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GODDARD SPACE FLIGHT CENTER/WALLOPS FLIGHT FACILITY

LAUNCH SITE SAFETY ASSESSMENT

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TABLE OF CONTENTS

SECTION 1.0: WALLOPS FLIGHT FACILITY RANGE CAPABILITIES

TABLE OF CONTENTS

SECTION 2.0: WALLOPS FLIGHT FACILITY RANGE SAFETY PROGRAM

LIST OF ILLUSTRATIONS

SECTION 1.0: WALLOPS FLIGHT FACILITY RANGE CAPABILITIES

LIST OF ILLUSTRATIONS

SECTION 2.0: WALLOPS FLIGHT FACILITY RANGE SAFETY PROGRAM

LIST OF TABLES

SECTION 1.0: WALLOPS FLIGHT FACILITY RANGE CAPABILITIES

SECTION 2.0: WALLOPS FLIGHT FACILITY RANGE SAFETY PROGRAM

LIST OF ABBREVIATIONS, ACRONYMS AND DEFINITIONS

AC - Alternating Current

Active Essential Personnel - Those individuals whose activities contribute directly to the performance of a potentially hazardous operation that is actually under way, and whose presence is mandatory for completion of the operation.

Actual Burst Pressure - The pressure at which pressure system components rupture while undergoing pressurize-to-burst testing.

ADCS - Advanced Data Acquisition System

ADP - Automated Data Processing

Aircraft Impact Probability - the probability of an object impacting an aircraft located at the edge of the aircraft hazard area.

ARB - Air Worthiness Review Board

AST – Associate Administrator for Commercial Space Transportation

Ballistic Coefficient - a number describing the descent characteristics of an object by combining the weight of the object with the aerodynamic drag coefficient and the reference area of the object.

Ballistic Wind - the average wind velocity vector over a specified altitude range.

Burst Factor - This quantity is equal to the MAWP divided by the design burst pressure.

Casualty Expectation - The probabilistic number of casualties due to conduct of a mission.

Caution Time - That time period when any hazardous device or system is present in the hazard area and is in a safe inactive state. When a caution time exists, non-participating personnel are allowed to enter the launch area only when authorized by the Operations Safety Supervisor. Active-essential and and by-essential personnel continue working during a caution time.

Clp and **Cld** - Aerodynamic lift coefficients

CSLA – Commercial Space Launch Act

Cma - Aerodynamic moment coefficient

Cmq - Aerodynamic pitch coefficient

CNa - Aerodynamic normal force coefficient

COMET - Commercial Experiment Transporter

Commonly Accepted Risk Level - $1.0X10^{-6}$ casualties per mission

Coriolis - the displacement of the impact point due to the earth's rotation during the vehicle flight.

Danger Area - That area including impact areas, abort areas, storage areas, or Danger Areas resulting from a system malfunction in which the hazards from impacting objects, debris, or toxic materials exceed the established maximum acceptable risk level.

CSLA - Commercial Space Launch Act

^{0} - degree, degrees

Descent Vector - the horizontal displacement vector of a descending object from the flight termination point to impact.

Design Burst Pressure - The pressure is a calculated test pressure that pressurized components shall withstand without rupture to demonstrate its design adequacy in a qualification test.

Dispersion - the statistical deviation of the actual impact point from the predicted impact point.

Dwell Time - the amount of time for the IIP to pass over a given land area.

Electro-explosive Device (EED) - An electric initiator or other component in which electrical energy is used to cause initiation of explosives contained therein.

Emergency System/Component - An emergency system component is any system/component which prevents a hazardous event from occurring or escalating. These systems normally experience very few cycles, but their performance is extremely safety critical. Typical emergency components are relief valves and shut-off valves. Typical emergency systems are fire suppression systems and emergency purge/vent systems

ER - Eastern Range

ESBM - Equipment Section Boost Motor

Failure - a system not operating as planned.

Flight Hardware - includes all propellant tanks, pressure vessels, lines and components that constitute airborne equipment on a launch vehicle or payload.

Flight Hazard Area - The operational area within which the risk due to impacting object(s) may exceed the established risk criteria.

Flight Safety - A philosophy and methodology whereby rocket, balloon, drone, and aircraft flight operations can be performed in a reasonable and prudent manner without undue risk to people or property or embarrassment to NASA or the United States Government.

FSO – Flight Safety Officer

Ft - foot, feet

FTS - Flight Termination Systems

Ground Safety - Those safety considerations, procedures, and resultant restrictions associated with hazardous systems during storage, handling, pre-launch, launch, and recovery/abort operations, whereby operations can be performed in a reasonable and prudent manner without undue risk to people or property or the environment.

GSE - Ground Support Equipment

GSFC - Goddard Space Flight Center

GTO - Geotransfer Orbit

Hangfire - A launch attempt where current to the vehicle initiator was delivered by the firing system and the vehicle failed to ignite as planned.

HAPS - Hydrazine Auxiliary Propulsion System

Hazard Area - the operational area within which the risk due to impacting objects may exceed the established risk criteria.

HF - High Frequency

HQ - Headquarters

IG - Inertial Guidance

Impact Area - The operational area within which one or more objects are predicted to impact in the vicinity of each other.

IIP - Instantaneous Impact Point

Inherently Safe - The predicted trajectory of the vehicle is based solely on the launch and dispersion parameters and on known system errors.

Instantaneous Impact Point (IIP) - The point at which an object would impact if thrusting were stopped at a given time.

IRIG - Inter-Range Instrumentation Group

IRIS - Silicon Graphics Computer System

ISA - Individual Support Annex

Kg - kilograms

Km - kilometers

Land Impact Probability - the probability of an object impacting in a land area.

Launch Abort - Premature and abrupt termination of a launch attempt because of existing or imminent degradation of mission success probability or safety requirements.

Launch Vehicle - Any rocket, rocket system, or balloon that is used to launch a suborbital or orbital payload, probe, satellite, or other experiment.

lb - pound

lbf - pound per foot

lbs – pounds(stopped here, Aerial 11 from Helv 11)

Leak-Before-Burst (LBB) - A fracture mechanics design concept in which it is shown that any initial flaw shall grow through the wall of the pressure vessel rather than bursting and causing catastrophic failure.

LEO - Low Earth Orbit

Lethal Area - the "footprint" of an impacting object.

LLV - Lockheed Launch Vehicle

LTA - Lighter-Than-Air

LTAS - Launch Trajectory Acquisition System Data

Maximum Allowable Working Pressure (MAWP) - The maximum operating pressure, to which operational personnel may be exposed, for a pressure system (vessel, tubing, piping, flex hose or component). This pressure is synonymous with Maximum Expected Operating Pressure (MEOP), as it is used and defined in MIL-STD-1522A.

Maximum Design Operating Pressure (MDOP) - The system pressure rating based on structural and functional reliability. This is the pressure at which relief devices are set and is equal to 110 percent MOP.

Maximum Expected Operating Pressure (MEOP) - This term, as defined in MIL-STD-1522A, is synonymous with MAWP. (See the definition for MAWP, as given above.)

Maximum Operating Pressure (MOP) - The maximum pressure a system shall be subjected to during static and dynamic conditions. Usually this pressure is less than or equal to MAWP. This pressure may except MAWP as long as pressurization(s) are performed remotely. However, under no conditions shall MOP exceed proof pressure.

MCDS - Mobile Command Destruct System

MD - Maryland

Megger Test - A measurement performed on EED's using a megohmmeter to determine the pin-to-case insulation resistance. The test is performed at a known voltage (normally 500 volts) to verify that the insulation shall not break down and permit EED ignition in this mode.

MGTAS - Medium Gain Telemetry Acquisition Systems

MHz - Megahertz

Misfire - A launch attempt in which current was not delivered to the vehicle initiator.

MRCS - Mobile Range Control System

MRR - Mission Requirements Request

MRTIIPS – Mobile Range Safety Real-Time Instantaneous Impact Prediction System

N - Nitrogen

NACA - National Advisory Committee for Aeronautics

NASA - National Aeronautics and Space Administration

NASCOM - NASA Communications Network

NE - Northeast

NLT - Not Later Than

nm - nautical miles

NOTAMS - An advisory issued to airmen listing restricted or hazardous airspace during certain times.

NOTMARS - An advisory issued to mariners listing restricted or hazardous areas during certain times.

NSBF - National Scientific Balloon Facility

NSWC - Naval Surface Weapons Center

OAM - Orbital Adjust Module

O_2 - Oxygen

OSD - Operations and Safety Directive

OSO - Office of Space Tracking

OSS - Operations Safety Supervisor

PAF - Payload Attach Fitting

Participating Personnel - Those individuals who are participating in the operation.

PCM - Pulse Code Modulation

PC - Personal Computer

PIK - Precision Injection Kit

PLF - Payload Fairing

Population Density - the number of people per square mile.

Power Switching - Power transfers where the net energy change exceeds 1.5 volts or 10 milliamperes.

PP - Present Position

PRD - Program Requirements Document

Probability of Impact - the probability of an object impacting in a defined area.

Proof Pressure - The test pressure applied to pressure systems or individual components without failure, leakage, or permanent deformation.

Psf - pounds per square foot

Public - All people that are not participants in the operation.

Range Safety - The ground and flight safety control associated with all phases of rocket, balloon, and aircraft operations.

RF - Radio Frequency

Risk - the likelihood of a particular unplanned and undesired outcome.

RSDS - Range Safety Display System

RSO - Range Safety Officer

RS - Recovery System

Ship Impact Probability - the probability of an object impacting a ship.

SM - Service Module

System Initiator - Any device that initiates the action of a system. This includes but is not limited to electro-explosive devices, non-explosive initiators, and exploding bridgewire initiators.

TM – Telemetry

TNT Equivalency - The explosive energy per unit mass of the energetic material in question (propellants in out case) divided by the energy per unit mass of TNT; this number is usually expressed as a percentage.

TOTS - Transportable Orbital Tracking Station

TV - Television

U.S. - United States

UHF - Ultra High Frequency

VCSPA – Virginia Commercial Space Flight Authority

VHF - Very High Frequency

WFF - Wallops Flight Facility

WICC – Wallops Integrated Control Center

WOTS - Wallops Orbital Tracking Station

WR - Western Range

WSMR - White Sands Missile Range

SECTION 1.0

WALLOPS FLIGHT FACILITY

RANGE CAPABILITIES

1.1 GENERAL INFORMATION

1.1.1 Local Area and Local Population Information

The Wallops Flight Facility (WFF) is located on Virginia's Eastern Shore at Wallops Island, Virginia. The northern border of the WFF launch site is the Chincoteague Inlet, which separates Wallops Island from the Chincoteague and Assateague Islands. These islands contain the town of Chincoteague, located about 3.9 NM from the launch site with a population of around 2,000, the Assateague National Seashore operated by the National Park Service, and a National Wildlife Refuge operated by the Fish and Wildlife Service. On both the east and south, the launch site is bounded by the Atlantic Ocean. On the west, it is adjacent to the Bogues, Powells, and Watts Bays, salt water marshes, and agricultural land. In addition, the sparsely populated towns of Assawoman and Atlantic, with populations of roughly 150 and 325 respectively, are located approximately 3.2 NM from the launch site, and Pocomoke City, MD, with a population of 4,000, is situated approximately 13 NM northwest.

1.1.2 WFF Range History/General Capabilities

In 1945, the National Advisory Committee for Aeronautics (NACA) established a launch site on Wallops Island, Virginia, under the direction of the Langley Research Center, then a field laboratory station of NACA. This site was designated the Pilotless Aircraft Research Station and assigned the mission of conducting research to supplement wind tunnel and laboratory investigations into the problems of flight. When Congress established the National Aeronautics and Space Administration (NASA) in 1958, (and absorbed Langley Research Center and other NACA field centers and research facilities), the Pilotless Aircraft Research Station became a separate facility - Wallops Station - operating directly under NASA Headquarters in Washington, D.C. It became Wallops Flight Center in 1974, and the name was changed to Wallops Flight Facility (WFF) in 1981 when it was incorporated into the Goddard Space Flight Center (GSFC), Greenbelt, Maryland.

Since 1945, there have been more than 14,000 suborbital and orbital research vehicles (sounding rockets, research aircraft, and research balloons) launched from or managed by the WFF by various launching agencies to obtain information on the flight characteristics of airplanes, launch vehicles, and spacecraft; and to increase knowledge of the Earth's upper atmosphere and the near-space environment. Several hundred experiments have been launched each year. Launch vehicles used have varied in size and power from the small Super Loki meteorological rocket to the four-stage Scout vehicle with orbital capability. Twenty-one orbital satellites were launched on the Scout vehicle from WFF. An additional 19 suborbital Scouts were launched carrying probes and simulated reentry experiments.

WFF evaluates each launch vehicle on a case-by-case basis. Vehicle type and size is limited principally by WFF range launch danger area restrictions. Vehicles launched from WFF can provide a low earth orbit payload capability of up to approximately 8,000 pounds at altitudes ranging from approximately 100 NM to 700 NM. However, range users contemplating launch from WFF must coordinate directly with range representatives to determine WFF's capability to support their particular launch vehicle. Limitations are due mainly to the lack of storage facilities for liquid fuels (plans are to expand this capability in the future as mission requirements dictate), launch danger areas that reflect vehicle performance, and consideration of impact areas of spent, separated stages. In addition to launch support capabilities, WFF has extensive tracking and data acquisition capabilities in three functional areas: radar, telemetry, and data systems, including communications and optics. Activities in these areas support the full range of rocket, balloon, aeronautical research and development, and scientific experimentation. Similar capabilities can be configured to support mobile operations worldwide. In addition, WFF owns and operates a satellite tracking facility as an integral part of the facility telemetry capability.

1.1.3 WFF Organization (SPOD)

The organizational flow from the GSFC to the Wallops Flight facility is shown in Figure 1-1. The Suborbital Projects and Operations Directorate (SPOD) is a first line directorate in the Goddard Space Flight Center Organization. The Director of Suborbital Projects and Operations exercises overall jurisdiction and is responsible for all GSFC/WFF operations. The SPOD's organization, which consists of three staff and seven line elements, is shown in Figure 1-2. The Policy and Business Relations Office, a staff element, is the initial point of contact for commercial agencies that wish to launch from WFF. The other two staff elements *are* the Safety Office and the Resource Management Office. The line elements are the Sounding Rocket Program Office, Balloon Program Office, Aircraft Office, Range and Mission Management Office, University Class Projects Office, Spartan Projects Office and the Shuttle Small Payload Projects Office.

The Suborbital Projects & Operations Directorate is responsible for:

- Managing and directing the NASA Sounding Rocket Program and the NASA Balloon Program.

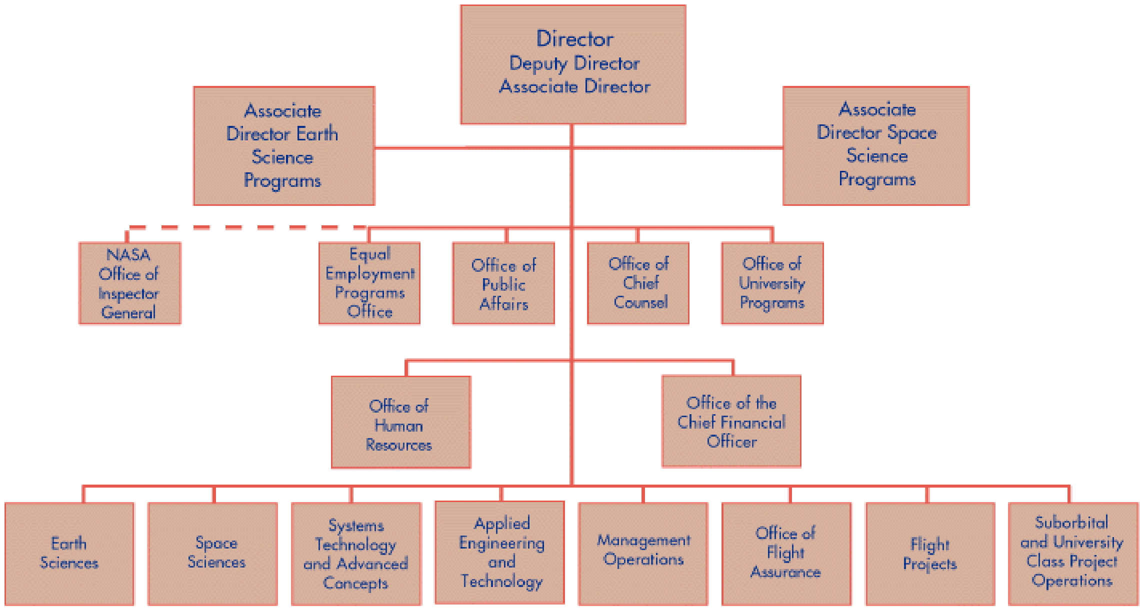


Figure 1 - 1: Goddard Space Flight Center (GSFC) Organization

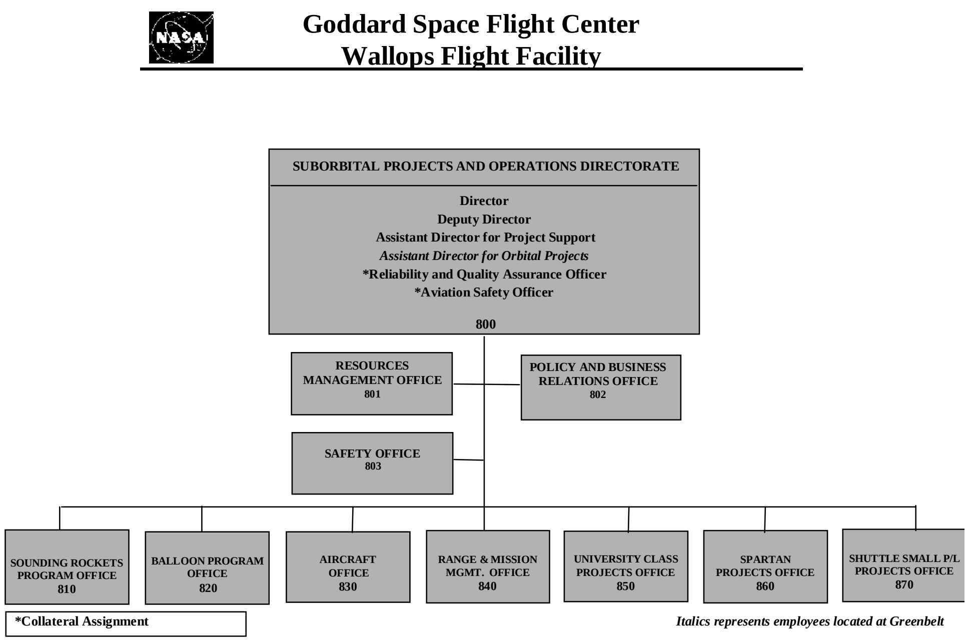


Figure 1 - 2 Suborbital Projects and Operations Directorate

- Providing mission management and payload design, development, fabrication and testing; experiment management support; launch operations; coordination of tracking and data acquisition; engineering and operational support, and technical skills required to conduct aerospace, and other project operations at Wallops and other locations around the world.

- Providing the project interface with NASA Headquarters, Program Offices, other government agencies, universities, private industry, and the international community.

- Planning and conducting launches of scientific payloads and aeronautical tests and other research development and related activities as requested by elements of NASA, the Department of Defense, private industry, other agencies and the worldwide scientific community.

- Maintaining and operating research facilities that include a range, research airport, and program support aircraft on a worldwide basis.

- Managing the National Scientific Balloon Facility in Palestine, Texas, and Ft. Sumner, New Mexico.

- Planning, managing, implementing, and evaluating of the Directorate's space launch commercialization programs. Seeking to match Directorate capability to national and international needs.

- Facilitating the transfer of new knowledge and aerospace technology from Wallops programs into the public and private sectors.

- Implementing educational outreach programs to share knowledge of and participation in Wallops mission programs with colleges, universities, high schools, and the general public.

- Providing management and operations support for assigned research and technology projects.

- Functions as the senior official on site at Wallops and assumes the ultimate responsibility or the safe conduct of all missions at Wallops.

1.1.3.1 Safety Office

The Safety Office is responsible for:

- Planning, developing, and providing functional management of policies and procedures for ground and flight safety, mission assurance, reliability and quality assurance.

- Performing engineering analysis of ground and flight safety systems, environmental conditions, and operating activities to assure safety reliability and flight worthiness..

- Establishing and approving safety precautions for protection of personal property and the public from hazards generated by ground and flight systems.

- Providing preflight and postflight analysis for flight missions.

- Providing multi-disciplinary engineering laboratories that support calibration standards and other for all types of electrical, electronic, electromechanical, and mechanical instrumentation

- Maintaining Wallops calibration standards and performs a wide variety of analyses on propellants, fuels, hydraulic fluids, and other similar chemicals.

- Providing services for all Wallops managed projects, both locally and at remote locations.

- Implementing the Wallops institutional safety program and manages the base fire department.

- Providing payload safety monitoring and reporting for the orbital projrcts including the UNEX, Shuttle Small Payloads Projects, and the Spartan Projects. This includes interfacing with the Office of Flight Assurance, KSC, and the JSC safety organizations.

- Providing reliability and quality assurance support for all WFF offices and missions.

1.1.3.2 Range and Mission Management Office

The Range and Mission Management Office is responsible for:

- Providing engineering, technical, and supporting skills necessary to plan, manage, and conduct aerospace and other project operations at Wallops and other locations.

- Planning and directing Wallops efforts to maintain and operate research facilities including the range, research airport program support aircraft, and the Wallops Orbital Tracking Station.

- Planning, organizing, and directing the NASA Sounding Rocket Program, the NASA Balloon Program, and other Lighter-Than-Air Program activities; providing program interface with NASA Headquarters, other government agencies, universities, private industry, and the international community.

- Providing mission and payload management for most of the programs' flight projects.

- Providing engineering support and management to the Balloon and Lighter-Than-Air Program activities, including management of the National Scientific Balloon Facility, feasibility studies, design studies, flight vehicles and systems development, test and evaluation, and data analysis and reporting.

- Managing the NASA university grants and contracts for assigned principal investigators supported by the Sounding Rocket and Balloon Programs.

1.1.4 WFF Test Range

The location of WFF in relation to nearby major population centers is shown in Figures 1-3, 1-4, and 1-5. It consists of three separate sections of real property:

Main Base - Administrative offices, technical service support shops, a rocket inspection and storage area, and an experimental research airport are located at the Main Base. In addition, there are such operational facilities as the Wallops Integrated Control Center (WICC), the main telemetry building, a large computer complex, and tracking and surveillance radars.

Wallops Island Launching Site - Wallops Island, a barrier island named after 17th century surveyor John Wallop, is located on the coast of Virginia approximately seven miles southeast of the Main Base. Separated from the mainland by two miles of marsh and inland waterway, the island launch site is approximately 7.0 NM long, 0.4 NM wide, and encompasses nearly 1,200 acres of real estate. It is connected with the Mainland by a causeway and bridge. Located on the island are launch sites, assembly shops, blockhouses, dynamic balancing facilities, some rocket storage buildings, and related facilities, several tracking radar's, and Navy Tenant Facilities (e.g. Aegis).

Wallops Mainland - The Wallops Mainland, a 0.5 NM strip at the opposite end of the causeway behind the island, is the location for the tracking and scientific radars, communications transmitter facilities, and command transmitters.

1.1.5 WFF Commercial Program Documentation

Potential commercial WFF range users make initial contact with the Policy and Business Relations Office. The range user provides information (normally a briefing with supporting data) regarding the type of mission to be flown, launch vehicle, payload, schedule, and planned range support requirements. The range representative in turn provides the potential range user with feedback as to whether the range can support their request and whether the proposed project falls under the purview of the Commercial Space Launch Act of 1984 (questions on license requirements should be discussed with the Associate Administrator for Commercial Space Transportation (AST)). Once it has been determined that WFF capabilities can accommodate user requirements, the established process for commercial activities to be performed at WFF is enacted. Documentation to implement the Commercial Space Launch Act (CSLA) within the WFF follows the flow depicted in Figure 1-6.

Wallops Flight Facility documentation requirements for user activities that fall under the provisions of the Commercial Space Launch Act are divided into three

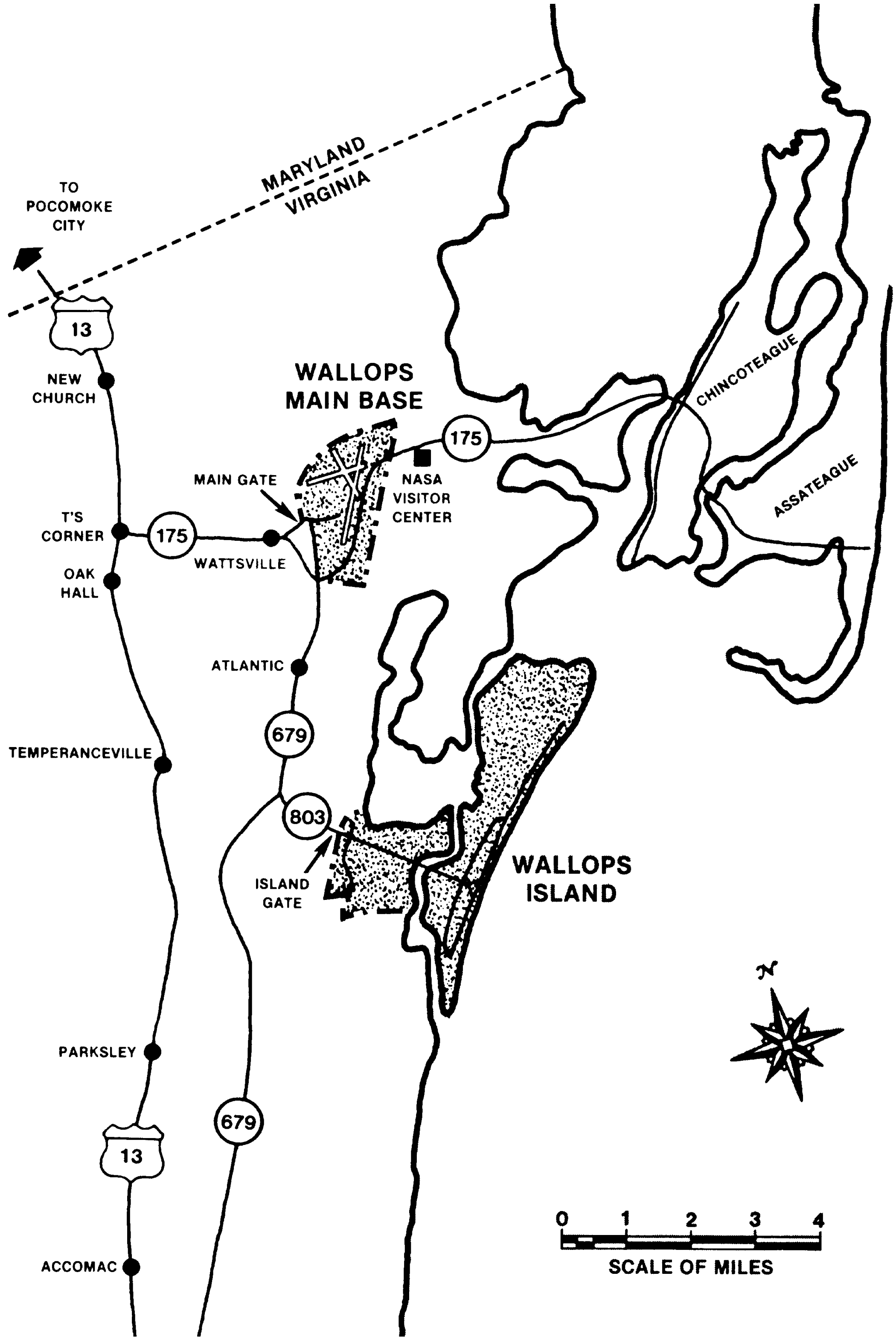
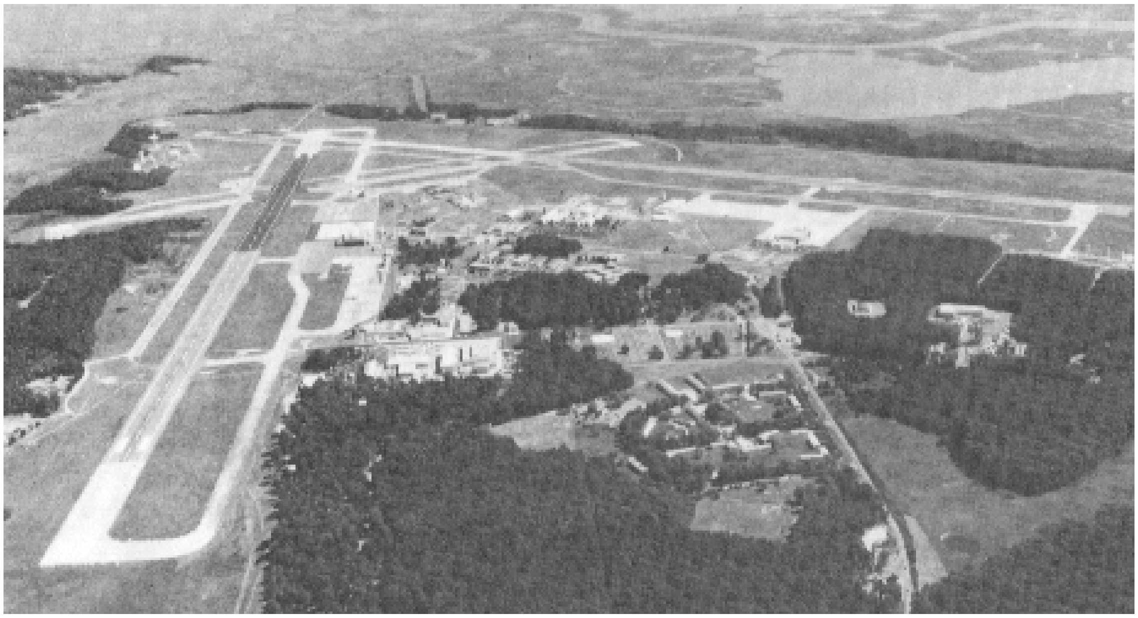


Figure 1 - 3: Wallops Overall



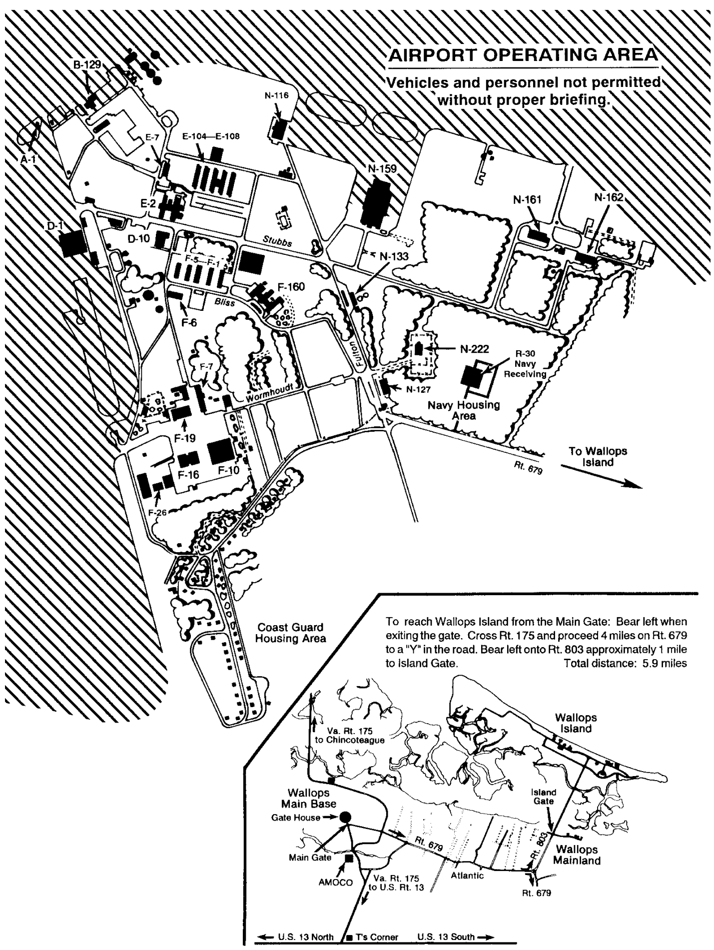


Figure 1 - 4: Wallops Main Base

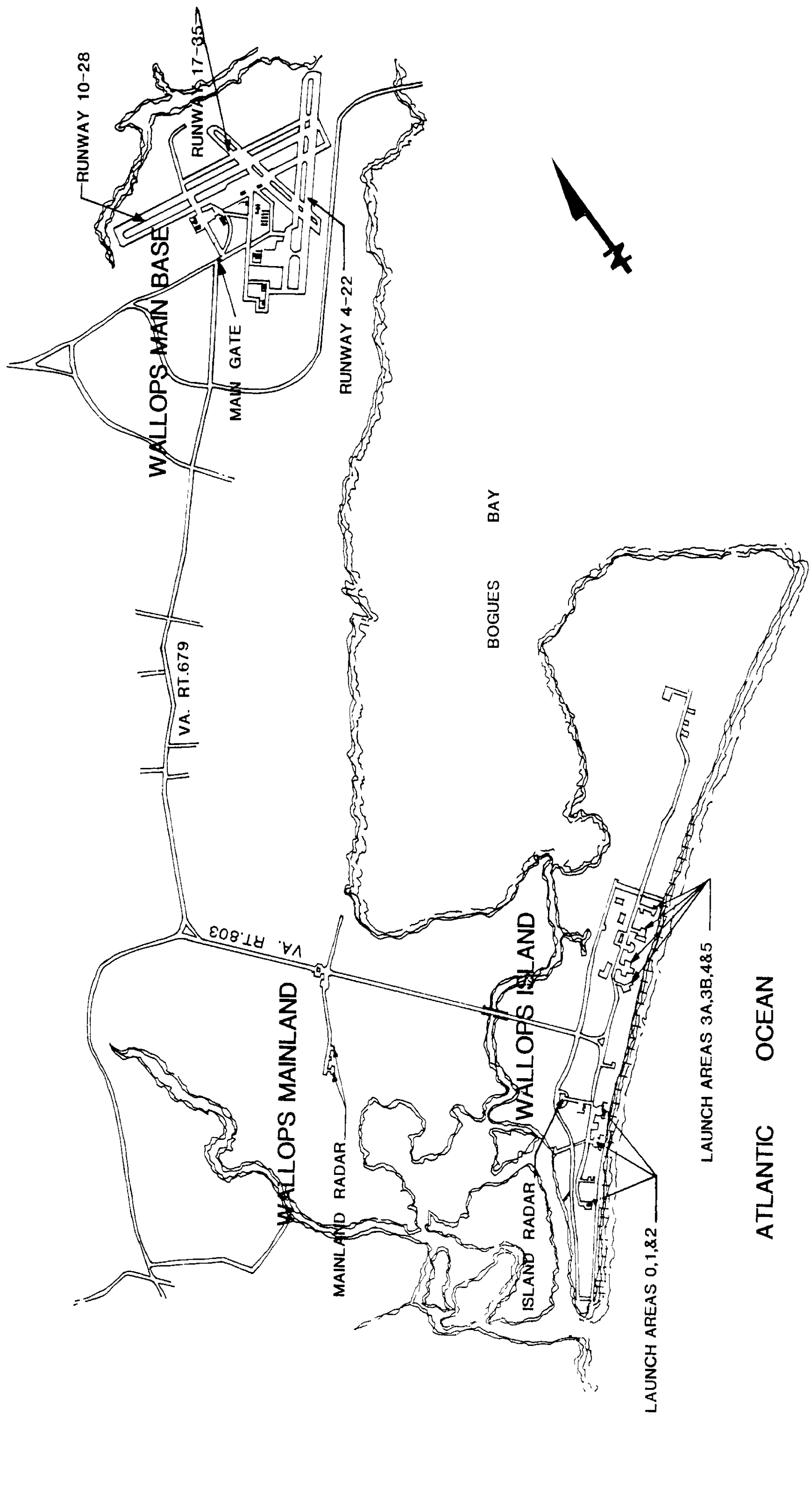


Figure 1 - 5: Wallops Island

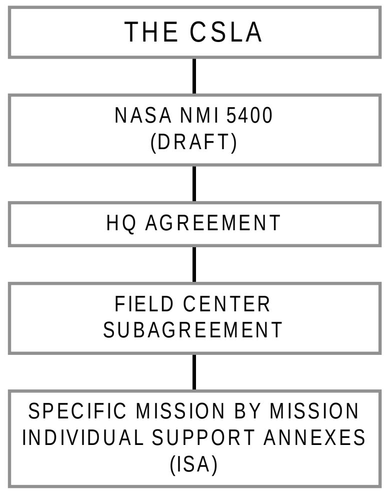


Figure 1 - 6: Commercial Space Launch Act Implementation

categories: agreements, requirements and interface documents. These documents define the support requirements for the Wallops Flight Facility and provide descriptive information to assist Wallops personnel in assuring requirements are satisfied satisfactory. Other forms of documentation related to safety provide the necessary data to safety office personnel to evaluate potential operational hazards and mission risk. The two types of documentation employed at WFF to promulgate policy, requirements, and response to both administrative and operational considerations are the HQ CSLA Agreement and the GSFC CSLA Sub-agreement. As a result of CLSA agreements established with the Virginia Commercial Space Flight Authority (VCSPA), a user may choose to become a customer of the VCSPA rather than establish a direct relationship with NASA. These documents are briefly discussed in the following paragraphs.

1.1.5.1 HQ CSLA Agreement

The HQ CSLA Agreement is a support agreement that is required between the potential commercial user and NASA Headquarters. This document is normally in effect for a period of five years after it is signed. However, there are provisions for renewal and extensions. The Agreement sets basic NASA policy and calls for a Subagreement at the GSFC, but does not commit the range user to proceed further. The Agreement is signed by a Headquarters NASA representative and the President, Chief Executive Officer or other corporate level representative of the commercial entity entering into the agreement who is authorized to commit corporate resources. The format of a typical Agreement is as follows:

- Scope and Authority
- Responsibilities
- Security

- Use of Government-Owned, NASA -Controlled Property and Services
- Financial Arrangements
- Allocation of Risks
- Patent and Data Rights
- Termination
- Disputes
- Priority and Delay
- Applicable Law
- Services Consistent with U. S. Laws and Policies
- Assistance with Claims
- Assistance of Rights
- Officials not to Benefit
- Revision Of Agreement
- Notices
- Approval

1.1.5.2 GSFC CSLA Subagreement

The GSFC CSLA Subagreement is an agreement required between the commercial user and GSFC. This document is in force for a period corresponding to that of the NASA Headquarters agreement. The subagreement also sets basic GSFC and WFF policy, and calls for Individual Support Annexes (ISA) with WFF, but does not commit the range user to proceed further. This subagreement is signed by the Director, Goddard Space Flight Center (see Figure 1-1) and a company representative for the commercial launch vehicle program, and is coordinated with NASA Headquarters. Once approved, the subagreement authorizes the user to visit the field center (WFF) and establish official contact with field center personnel, e.g., the Policy and Business Relations Office (see Figure 1-2), and operations and safety personnel. The format of a typical subagreement is as follows:

- Scope and Authority
- Acknowledgments and Understandings
- Use of Government Facilities and Services
- Support Requirements
- Environmental Issues
- Safety
- Financial Arrangements
- Revision and Termination

- Public Information
- Effective date and Duration
- Financial Status Report

1.1.5.3 Enabling and Operational Documentation

Enabling documentation such as annexes, requirements, directives, and plans provide the basis for establishing needs and support responses for the program ground processing and flight operations. Individual Support Annexes (ISA's) between WFF and the user are administered by the Policy and Business Relations Office. ISA's are mission-specific operational tools that describe the user's needs and NASA support. These annexes are signed by the WFF Director of Suborbital Projects and Operations, and the commercial company representative. At this point, a range support manager from the Range & Mission Management Office is assigned to the mission and becomes the range interface. There are five distinct ISAs; however, only those needed are implemented. The five ISAs and their associated operations documentation include:

a. ISA Task A covers Pre-mission Feasibility Planning, Range Support Analysis, and Cost Estimation Analysis. This ISA is implemented for those situations where the commercial user does not have a specific mission but does need to interface with WFF. All costs for this support are the user's responsibility. Some examples include range safety studies to determine launch feasibility, operational studies, travel to planning meetings, or cost estimation in preparation for a proposal.

b. ISA Task B covers support of the (Launch Company Name) commercial space launch of (Payload Name or Payload Company Name) satellite or sub-orbital payload. This ISA is implemented to cover support for each launch/mission to be conducted by WFF. It is used for all launch activities at WFF and all mobile missions. This support includes but is not limited to a schedule of facility use, schedule of field activities, PRD, schedule of insurance coverage, FAA launch license, frequency utilization plan, gross hazards analysis, flight safety data, ground safety data package, hazardous procedures package, and FTS test reports for vehicles such as Pegasus or other innovative launch concepts/programs. These programs may require off-range system support and/ or coordination with other ranges or non governmental interests. The full range of facilities, instrumentation, and services that are available are described in this ISA

c. ISA Task C covers NASA support of launches from established launch sites external to WFF, e.g. Alaska, Brazil. It includes rockets and other vehicles/payloads being launched by US Companies subject to the CSLA from an external launch site/range. This ISA is an abbreviated version of the Task B

ISA. This ISA is intended to be used to cover NASA support activities that involve multiple support agencies and launches at locations external to WFF.

d. ISA Task D covers Public Affairs. Task D is a joint plan on how public affairs will be accomplished for all missions, participants, and launch locations.

e. ISA Task E covers Improvement of Facilities. This ISA is used only if NASA facilities are to be modified, or new facilities constructed on NASA property with funding by the commercial user. In order to implement Task E, an Annex or Addendum to the CLSA agreement must be instituted.

f. Program Requirements Document (PRD) is a detailed, full-program, planning document normally required for complex or long lead-time programs. When prepared by the user in accordance with the Universal Documentation System Handbook and submitted to GSFC, it meets the Mission Support Proposal section requirements of the subagreement. The document details the WFF support requirements desired for each mission. In addition to describing the requested support, the PRD provides additional technical information and project descriptions.

g. Mission Frequency Utilization Plan is a detailed plan prepared in accordance with section 4.4 of the ISA TASK B00X series of documents. It is the controlling document for all the frequencies required to conduct the mission (radar, telemetry, command destruct, and radio communications). A draft is due approximately 120 days before support is required and the final document is due 15 days before the mission takes place.

h. Operations and Safety Directive (OSD) is prepared and signed by the Range Support Manager for each launch operation in accordance with the GSFC/WFF Range Safety Manual for that launch. The OSD includes a description of the operation being performed; support requirements; Go/No Go requirements; aviation, ground, and flight safety plans; special operational procedures; and countdown procedures. It is approved by the Chief of the Safety Office and the Chief of the Range and Mission Management Office It is then published by GSFC/WFF and delivered not later than 21 days prior to the operation.

The agreements described above and some of the other pre-mission enabling documents are unique to CSLA activities while the operational requirements documents are standard for any range user at GSFC/WFF. Figure 1-7 is a flow chart showing the various documents and their relationships.

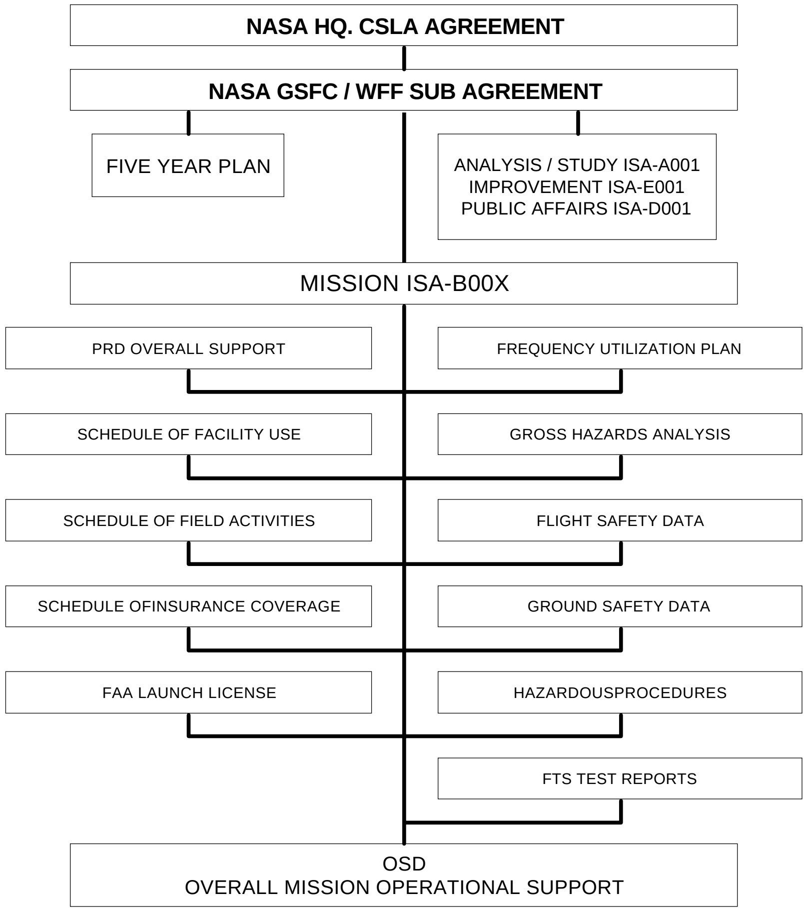


Figure 1 - 7: Typical Commercial Launch Support Requirements Flow

1.2 RANGE DESCRIPTION

The Wallops Launch Range originates on Wallops Island, Virginia, and extends out into the Atlantic Ocean. Figure 1-8 shows the near coastal area and the operational impact area associated with WFF launches, while Figure 1-9 shows ground traces for orbital launches into inclinations of 38° or 60°. The principal Wallops Island facilities and launch sites are used to process, check-out, and launch rocket boosters that carry payloads on sub-orbital or low earth orbit trajectories.

1.2.1 Complexes and Facilities

The types of complexes and facilities located at WFF include launch pads, launchers, blockhouses, booster preparation and payload check-out buildings, dynamic balance equipment, a timing facility, wind measuring devices, communications and control instrumentation, TV and optical tracking stations, surveillance and tracking radar units, tenant and other supporting facilities. Hazardous materials storage is also available for rocket motors and chemicals.

Acreage is available for future construction to support launch vehicles with alternative propulsion systems, such as liquid or hybrid systems. In general, launch pads are located on the South part of the island in order to provide flexibility in supporting various mission flight azimuths.

The Wallops Island launch complexes and facilities are located adjacent to the beach (see Figure 1-10 for WFF complex and facility locations). Descriptions of inactive areas, active commercial pads, and facilities are included in the following paragraphs:

M-16 and M-20 - These are processing facilities located to the North of the E/W runway. The specific area is located in the lower left corner of Figure 1-4 just to the left of the runway in the band of trees. M-16 is a payload processing facility with two clean rooms (Figure 1-11) and M-20 is used for Pegasus launch vehicle processing (Figure 1-12).

Launch Area Number 0A - Approximately 1,200 feet north of pad 0B and just north of Blockhouse Zero (Z-40) is the new CONESTOGA complex (see Figure 1-10). This launch site consists of a pad and a transportable service structure (see Figures 1-13 and 1-14). The service structure is a modular design capable of being broken down and transported to any site with an appropriate concrete slab. Blockhouse Z-40 (Figure 15) is used as the terminal building for the CONESTOGA launcher. The terminal building serves as the locus of all circuits interfacing with the pad and vehicle as well as a support building for staff and monitoring equipment until evacuation of the launch hazard area is required. The blockhouse covers ~1,830 ft^2. It has two bays and two equipment rooms that can also be used as office space (see Figure 1-15) when safety allows.

Launch Area Number 0B - Launch Area 0B is located on the southern end of Wallops Island (see Figure 1-10) and is currently designated as the Virginia Commercial Space Flight Authority launch facility. It includes the universal expendable launch vehicle launch mount and several small utility buildings. Reactivation of the site for use by the Virginia Commercial Spaceport Authority is currently under consideration.

The Z-41 facility is located on the South end of the island adjacent to Pad 0A (See Figure 1-10). It was formally used as the Naval Surface Weapons Center Combat System Performance Test Facility. Its three floors have a total area of 8,275 ft^2 with the ground floor covering 5650 ft^2. Z-41 is currently evacuated and in a mothball state. (See Figure 1-16).

Launch Area Number 1 - This is the site of a 50K rail launcher used to support large suborbital sounding rocket missions (see Figure 1-10). The launch site is currently active.

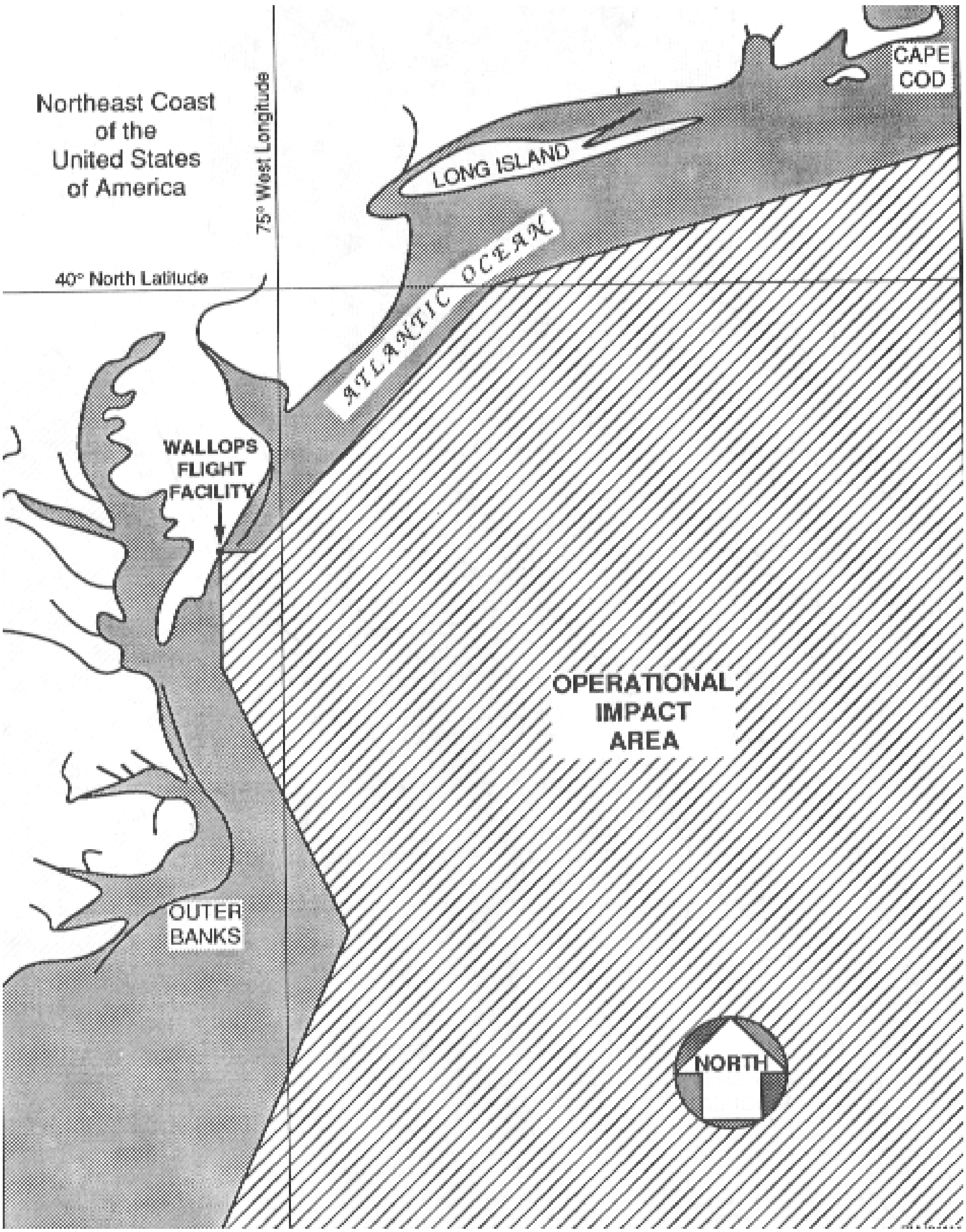


Figure 1 - 8: WFF Range (Impact Areas)

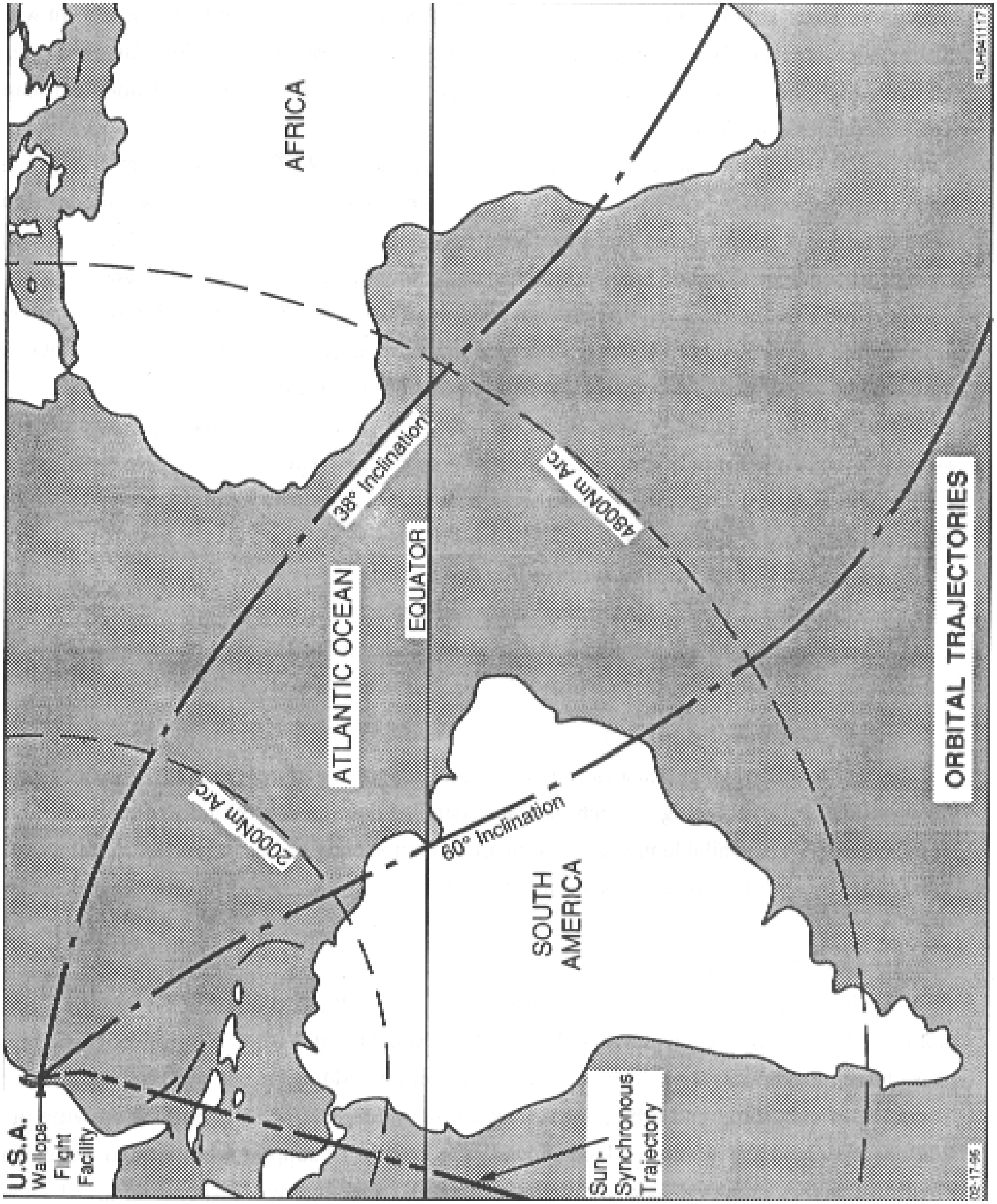


Figure 1 - 9: WFF Range (Range of Inclinations)

Figure 1 - 10: Wallops Flight Facility Complexes and Facilities

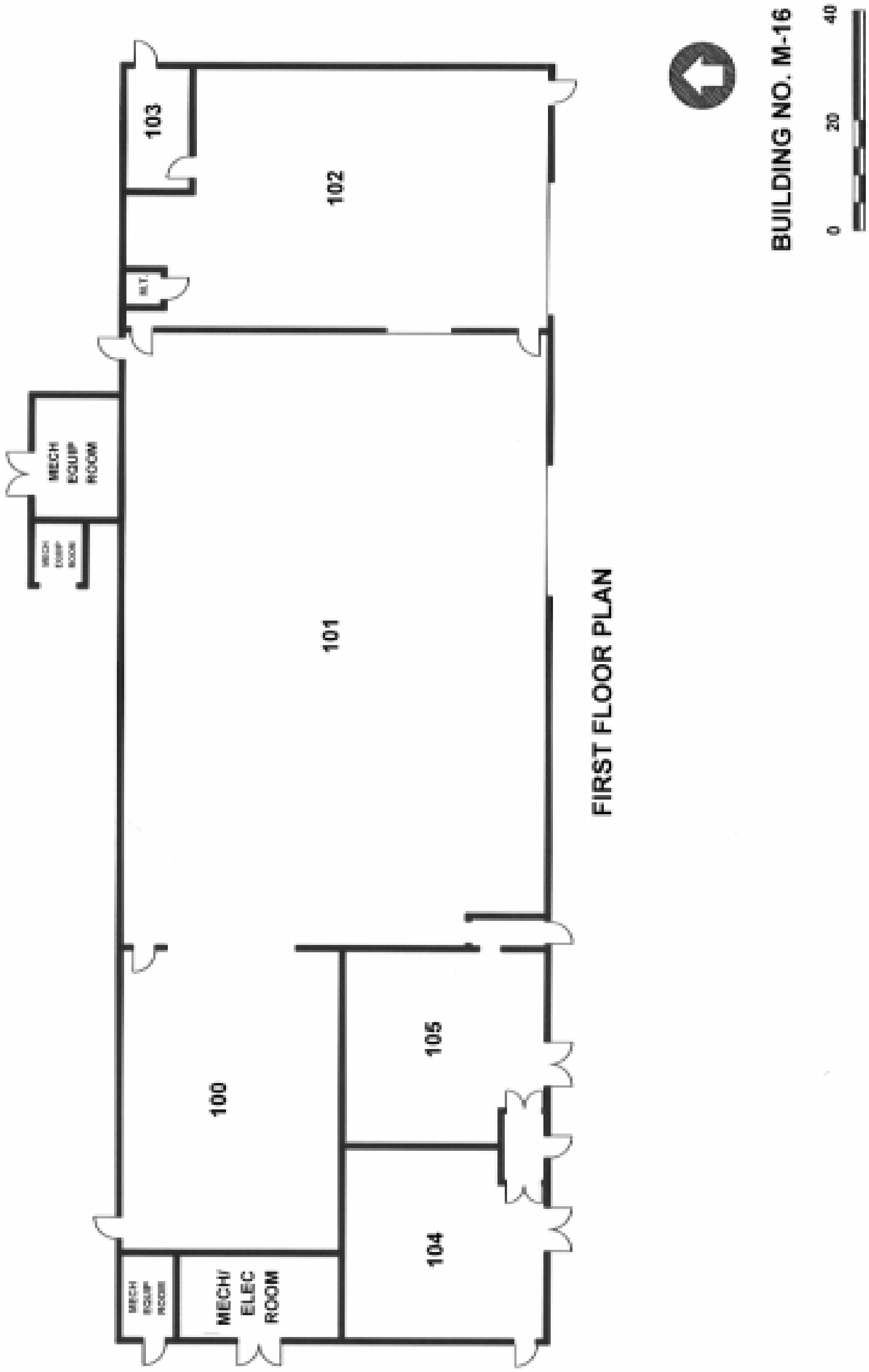


Figure 1 - 11: M-16, Payload Processing Facility

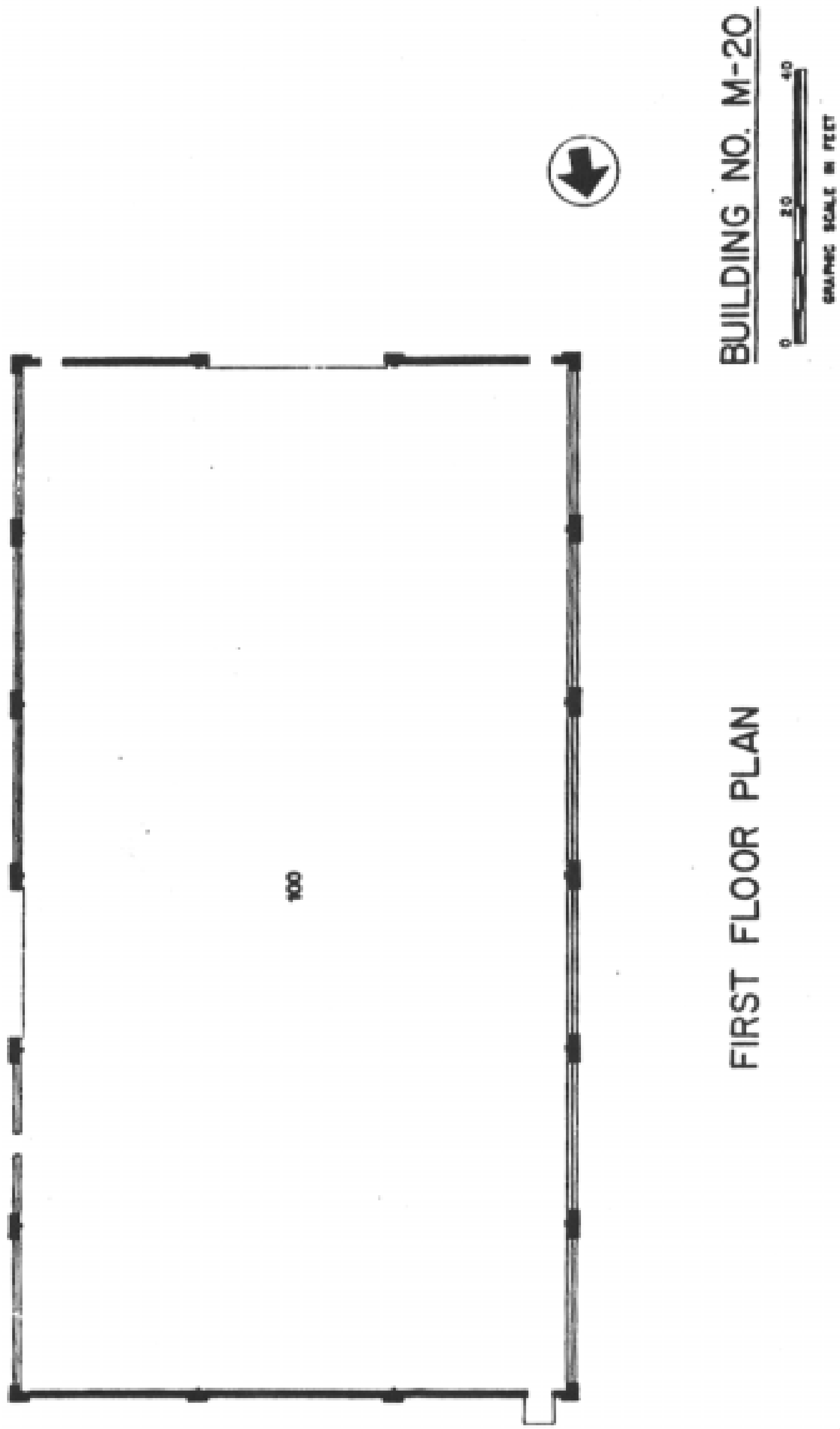


Figure 1 - 12: Pegasus Launch Processing, M-20

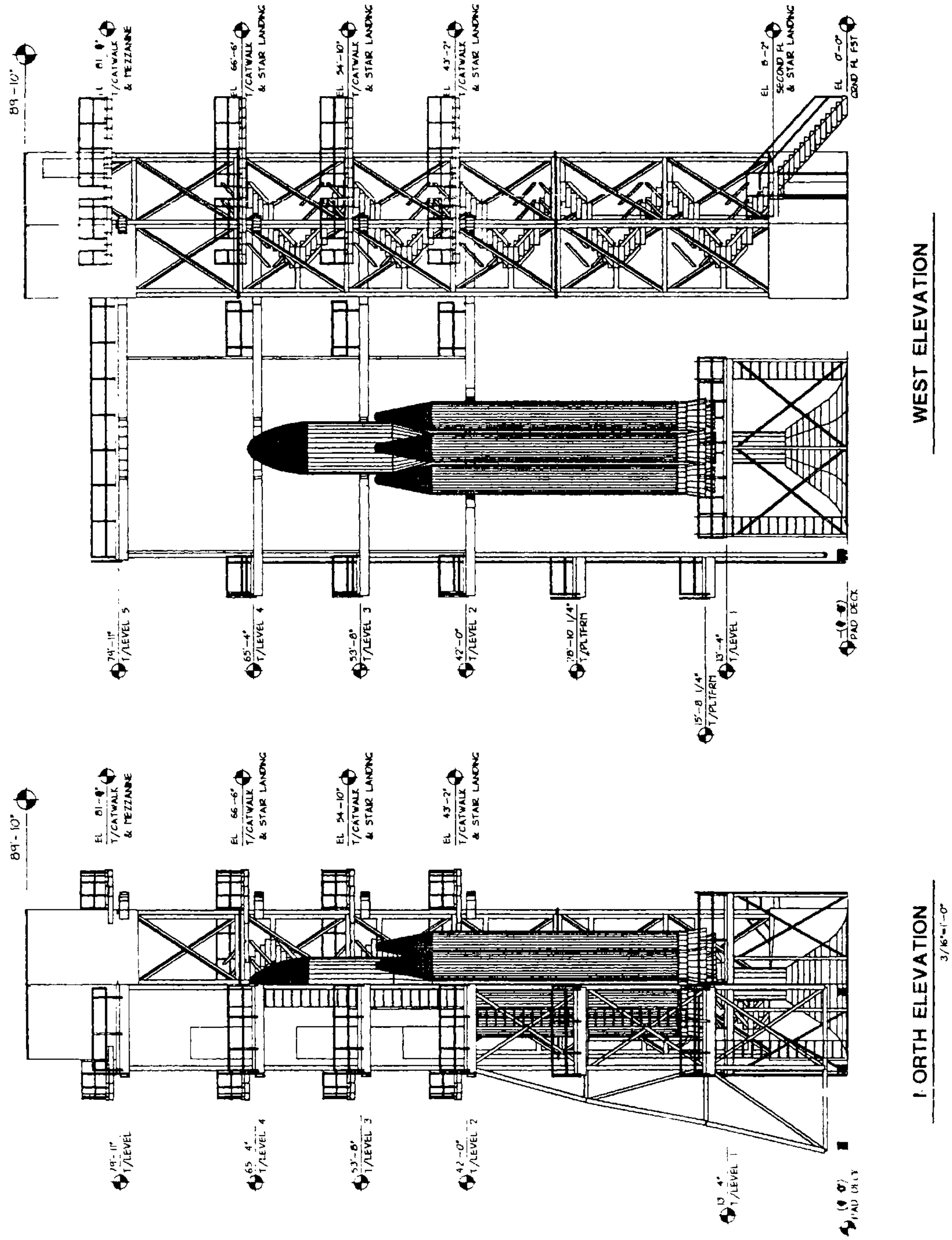


Figure 1 - 13: Pad 0A Elevations

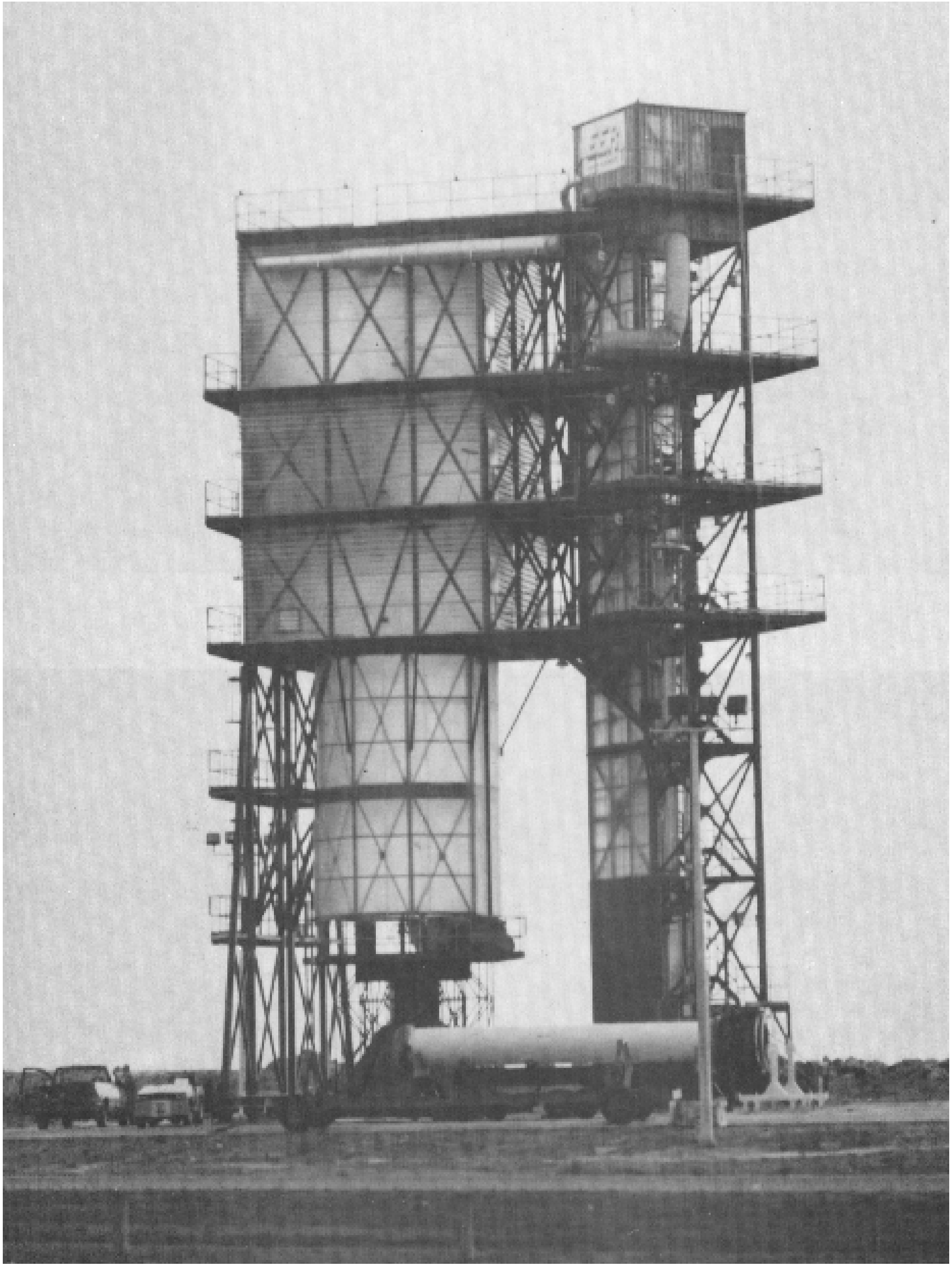


Figure 1 - 14: Multilevel Commercial ELV Launch Complex Pad 0A

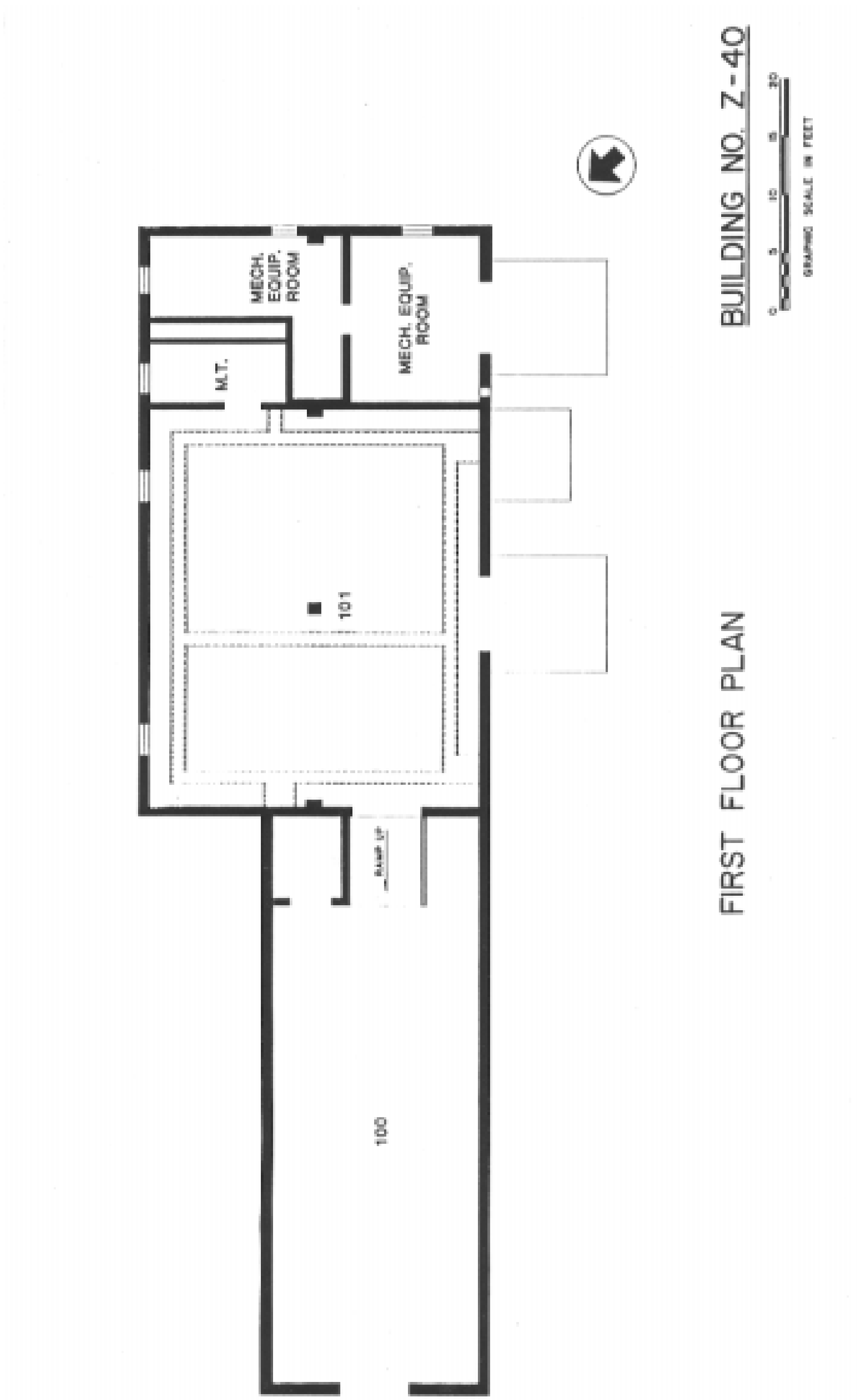


Figure 1 - 15: Building Z-40, Blockhouse Zero

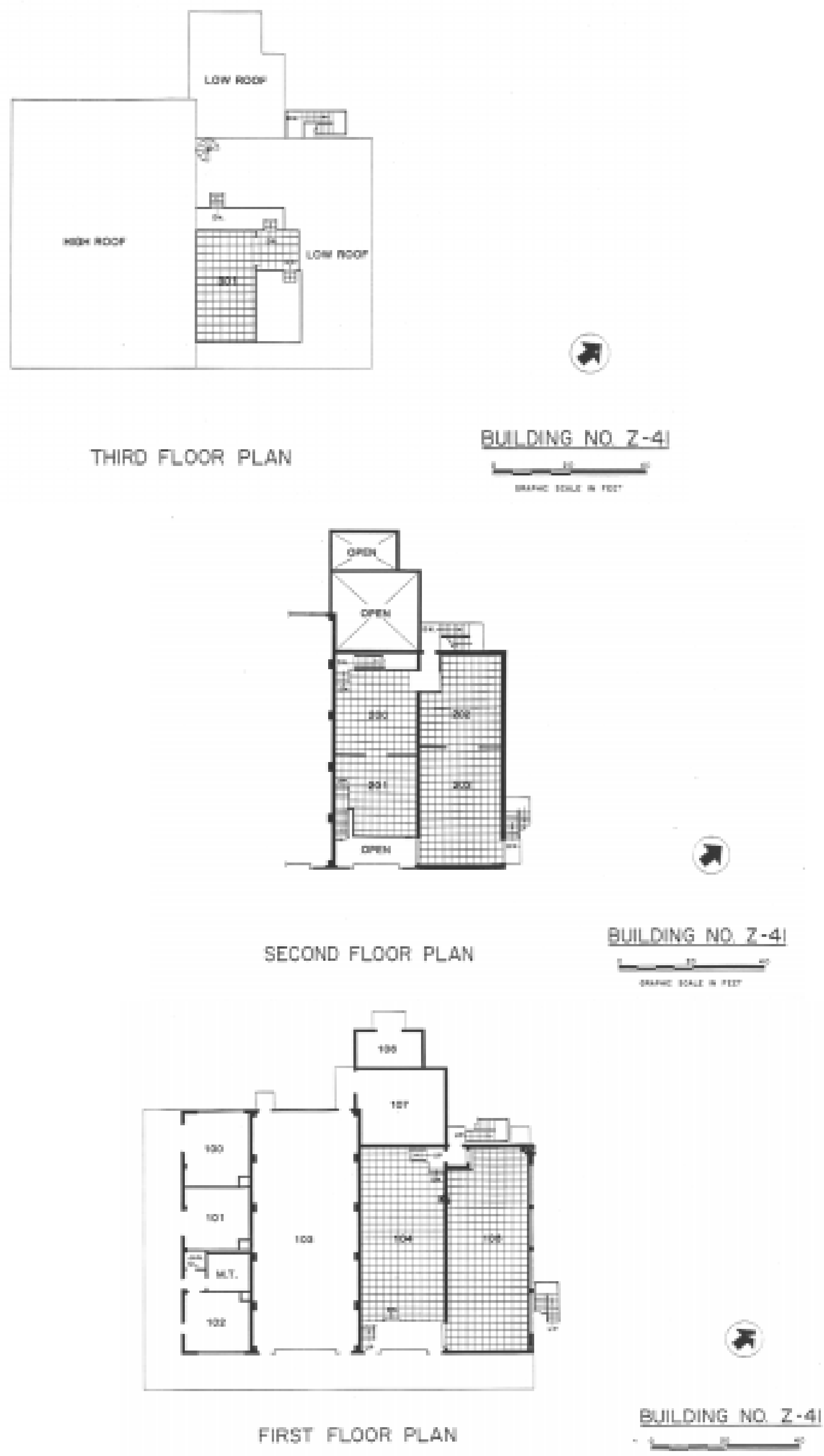


Figure 1 - 16: Building Z-41, Vehicle Assembly

Launch Area Number 2 and Blockhouse Number 2 (Y-30) - Several types of launchers are located in this area (see Figure 1-10) to accommodate all small to medium size suborbital vehicles/missions. The types of vehicles carrying scientific experiments which are being, or have been, launched from this launch area include Nike-Tomahawk, Orion, Nike-Orion, and Black Brant sounding rockets, as well as the small Arcas and Super Loki meteorological rockets. The blockhouse (see Figure 1-17) has two bays/mechanical equipment rooms and 12 office/equipment rooms of varying sizes encompassing a total of 2,725 ft^2. Assembly Building Y-15 (Figure 1-18) supports this launch site as well. It has eight bays/equipment rooms and two office/equipment rooms encompassing 8240 ft^2.

Payload Facility (X-15) - X-15 is a two story facility located just south of the intersection of the coast road and the causeway from the mainland and just north of the Launch Area # 2 (see Figure 1-10). On the ground floor it has a large open area (single bay) covering 2,370 ft^2 that is used for non-hazardous payload processing. In addition it has several conference rooms, numerous offices, and lab space. The facility is used for both payload assembly and damage control (see Figure 1-19). Damage control (range emergency forces - fire and security) are located in the Southwest end of the building.

Launch Area Number 3 (Pads 3A and 3B) - Pad 3 is the pad from which the Scout vehicle has previously been launched (see Figure 1-10). It is located approximately one mile from the intercoastal waterway and two miles from the "public domain". Both pads employ a horizontal type launcher that allows the vehicle to be prepared and held in the horizontal position until a short time before launch The mothballed Scout Launcher is located on Pad 3A. On Pad 3B is an environmentally covered 20K launcher for sub-orbital launches (See Figure1-20). Pad 3B is used for some of the larger sounding rockets and special purpose missions, such as the Aries vehicle.

Checkout & Assembly Shop (W-65) - W-65 is located just west of Launch Area 3. It is a six bay building (See Figure 1-21) covering 13255 ft^2 and is designed for vehicle checkout and assembly of launch vehicles. Previous uses have been for the Scout vehicle and its payload. W-65 has an internal class 10,000 clean room for payload assembly and several smaller rooms, one for hazardous testing and the others for non-destructive testing.

Blockhouse Number 3 (W-20) - This concrete, dome-shaped building north of Launch Area No. 3 is the blockhouse from which operations on Launch Areas 0A, 0B, 1, 3, 4, and 5 are controlled (See Figures 1-10 and 1-22). The walls of this building are eight feet thick, reinforced concrete. It was built to withstand a direct hit by the Scout vehicle. It has multiple bays from which concurrent operations can be supported. For example, a Vandal, a Conestoga, and a sounding rocket in varying phases of operation could be supported at the same

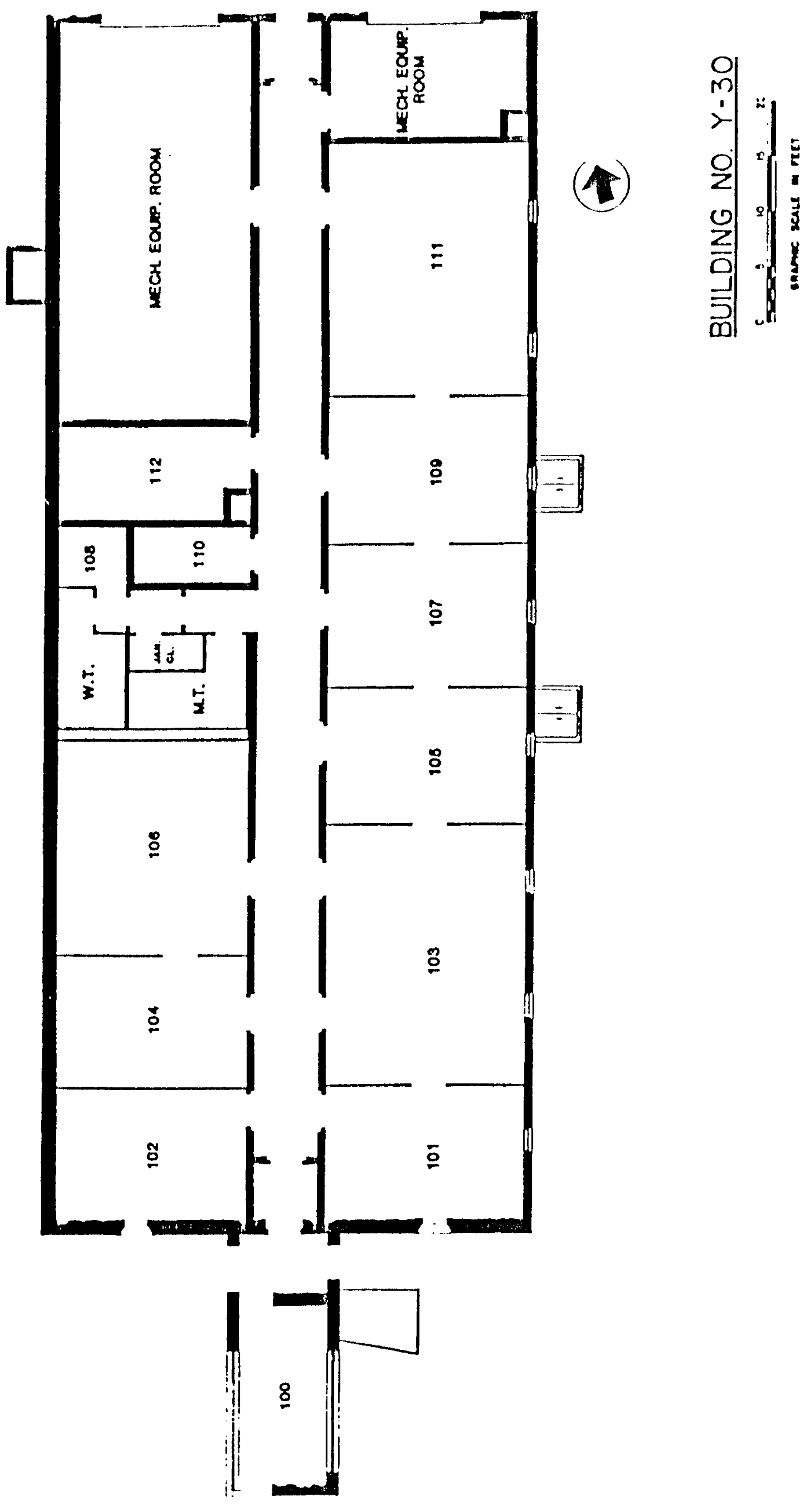


Figure 1 - 17: Building Y-30, Blockhouse Two

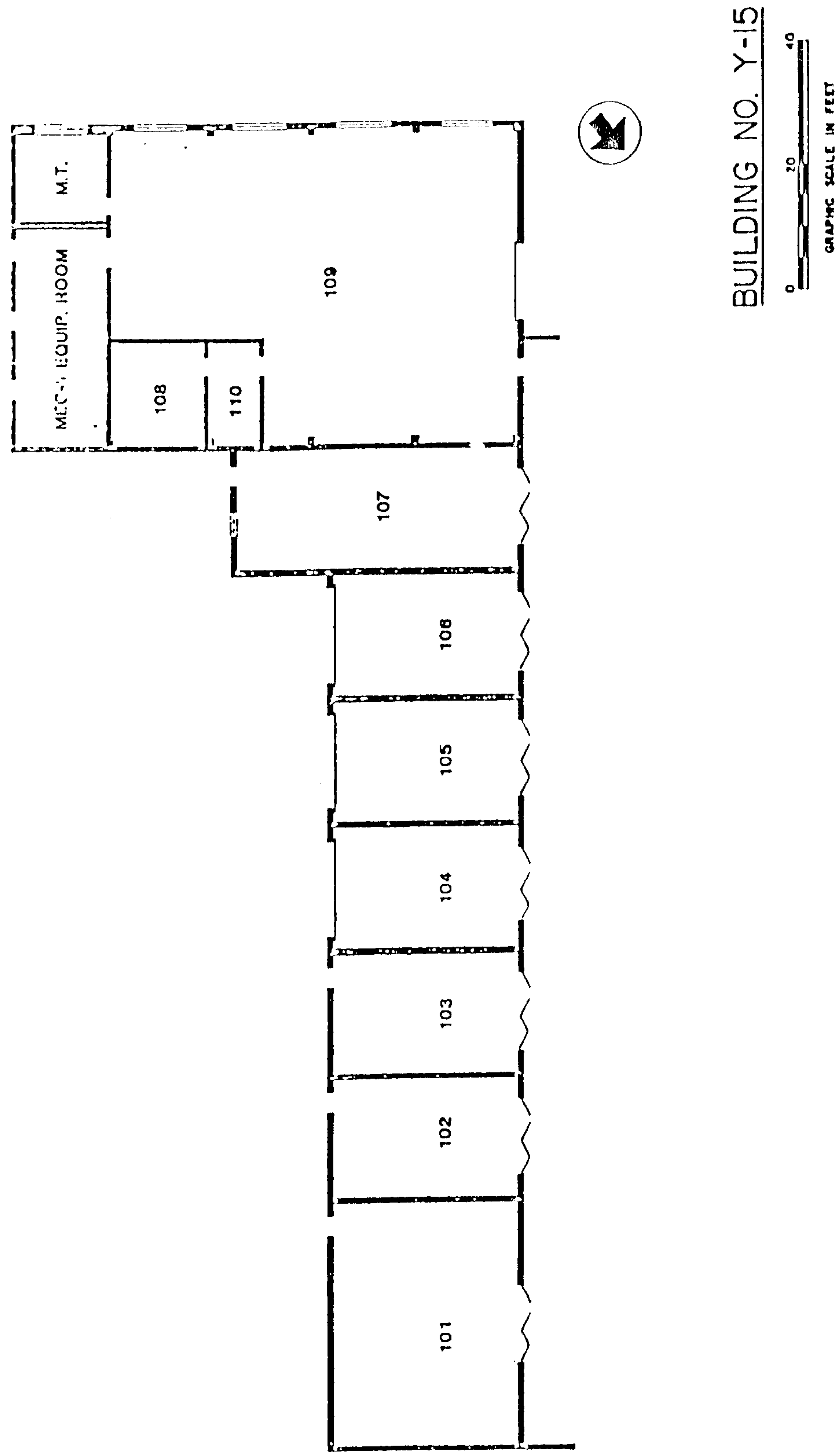
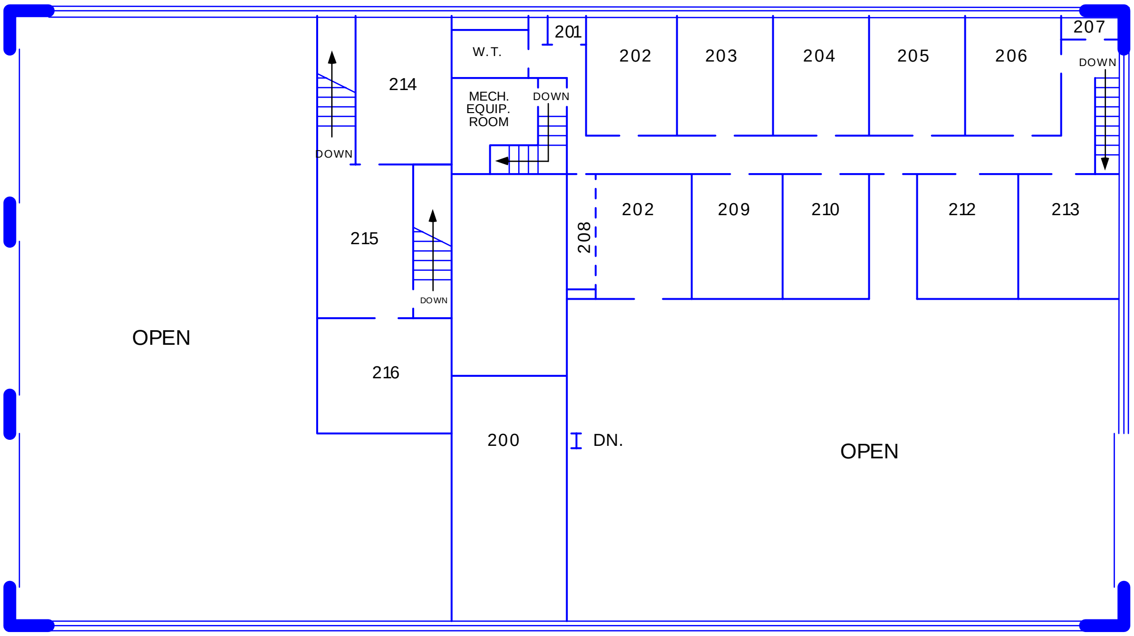
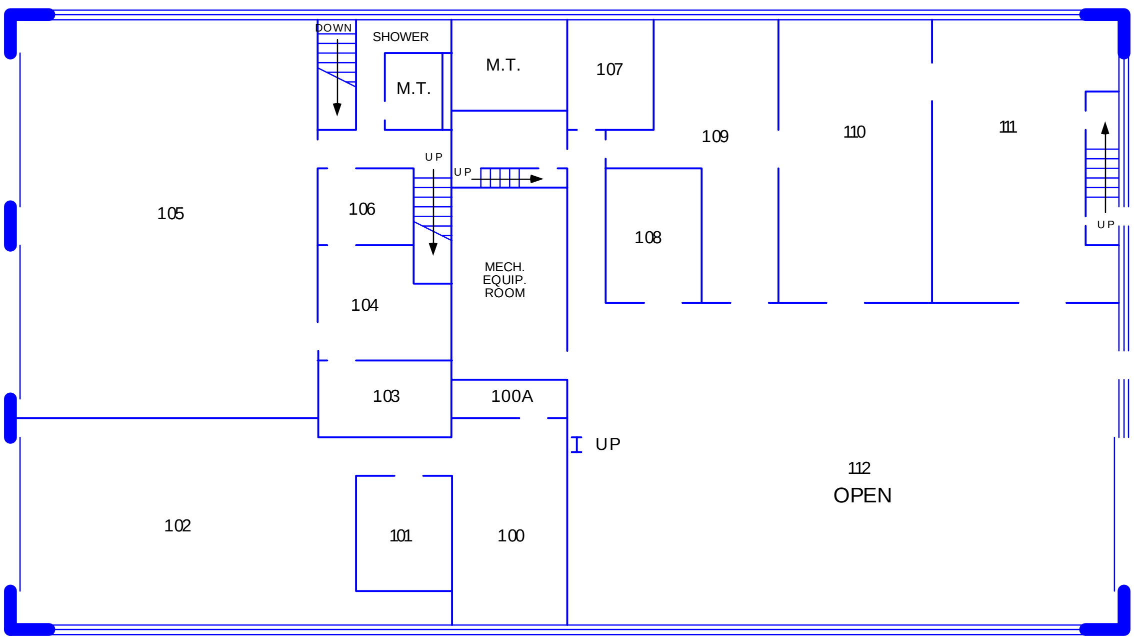


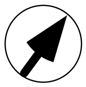
Figure 1 - 18: Building Y-15, Vehicle Assembly



SECOND FLOOR PLAN



FIRST FLOOR PLAN



BUILDING NO. X-15

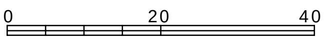


Figure 1 - 19: Building X-15, Payload Processing

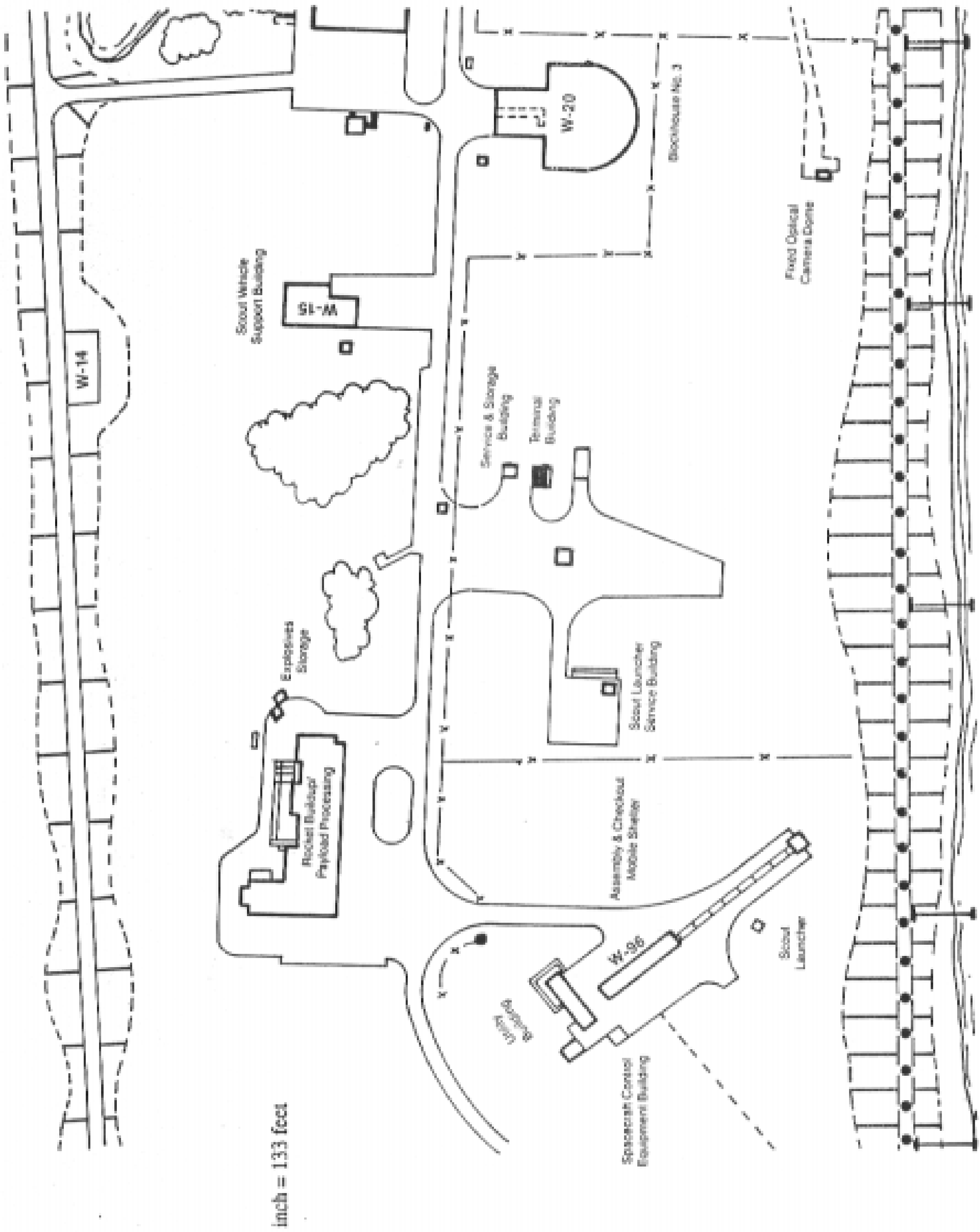


Figure 1 - 20: Launch Area 3, Scout

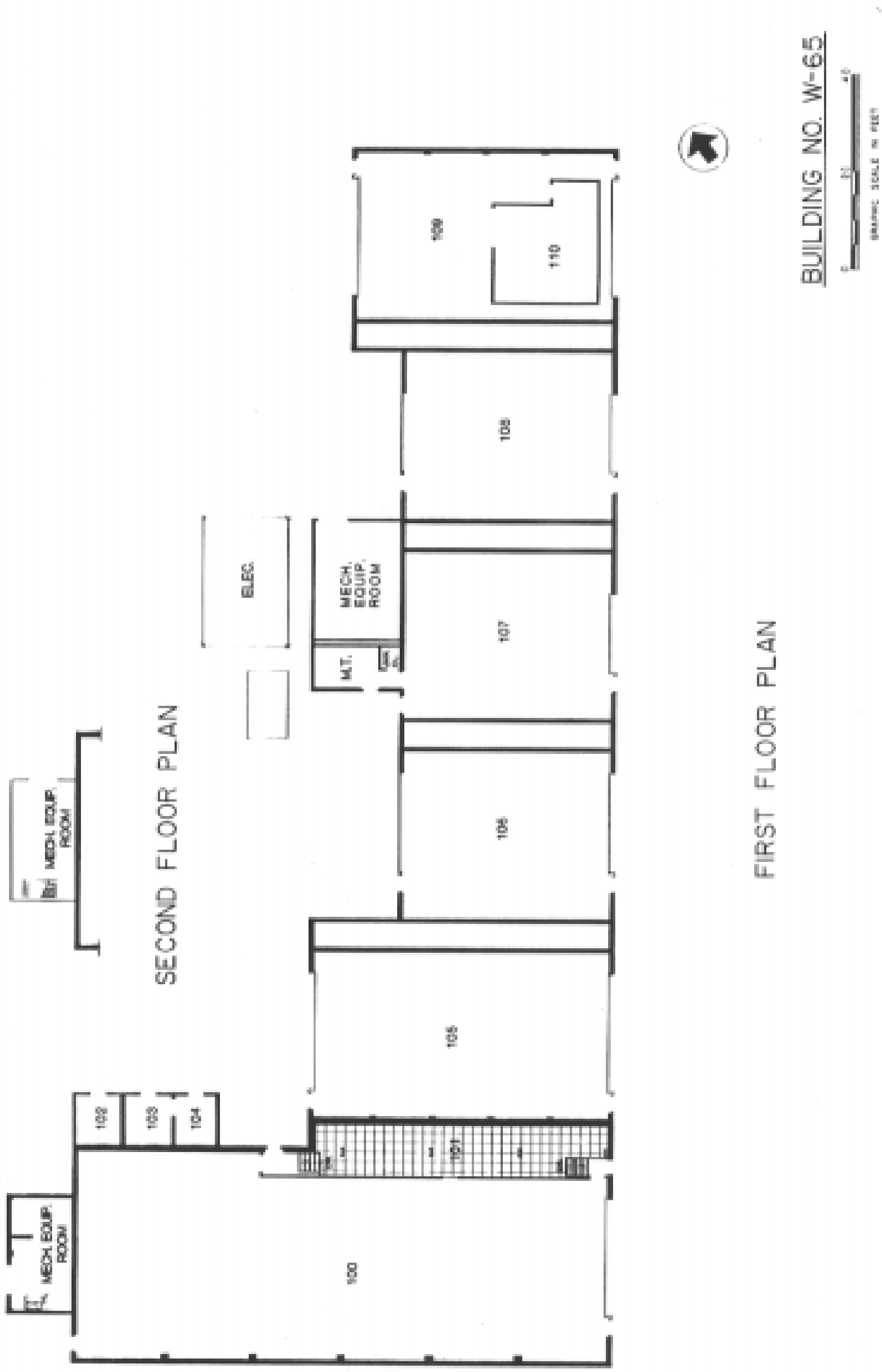
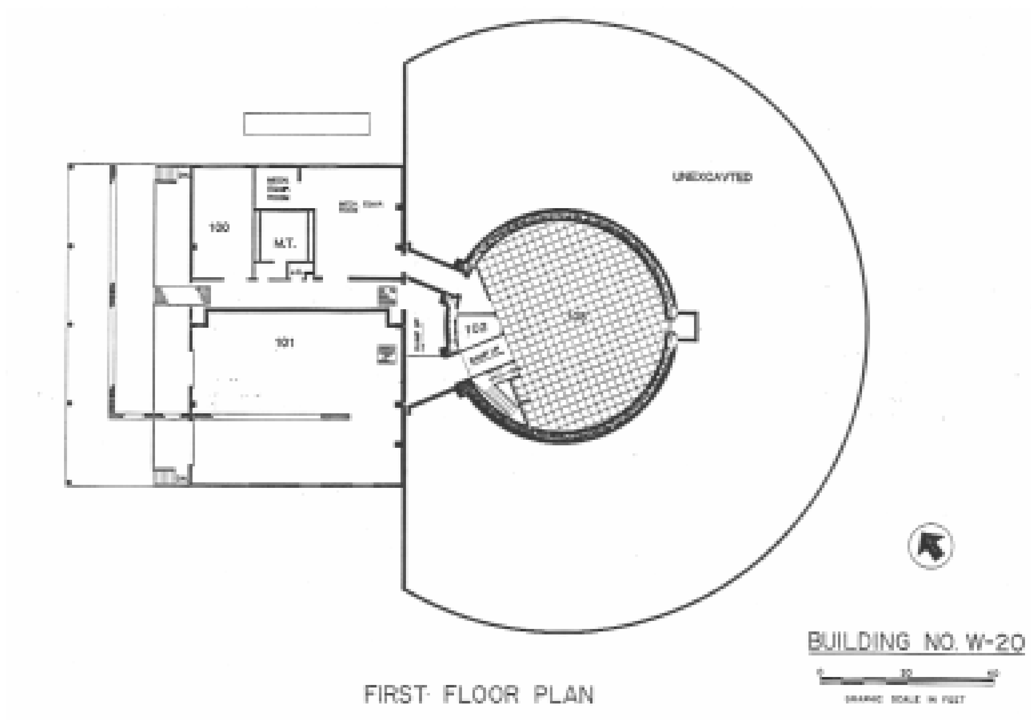


Figure 1 - 21: Building W-65, Vehicle Assembly



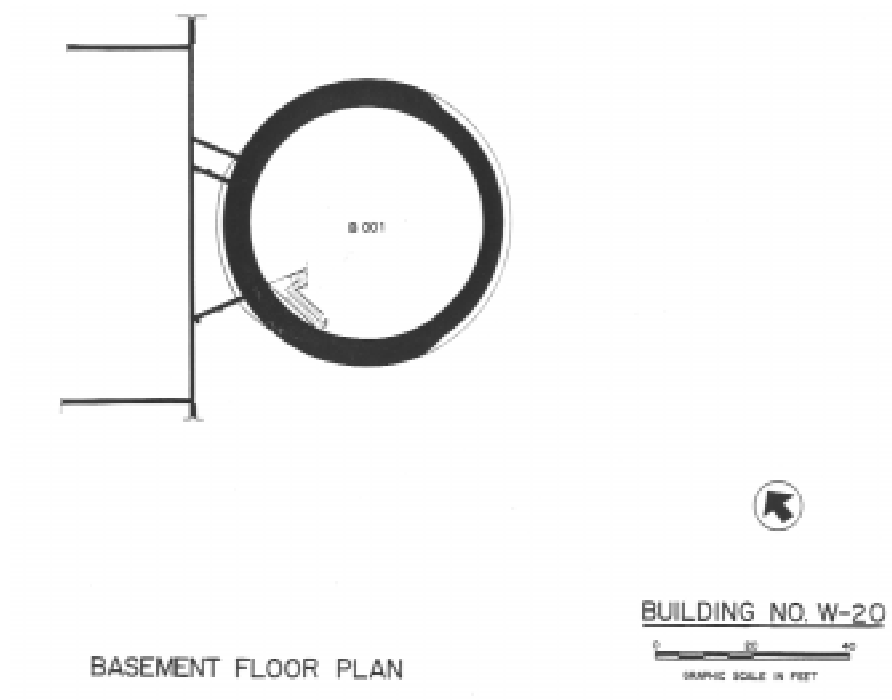


Figure 1 - 22: Building W-20, Blockhouse Three

time. Tables with PC-based workstations are set up to provide user support. Data from pad cameras and other external data sources are routed to monitors in each bay area.

Launch Area Number 4 - This area is currently inactive but was previously used for sounding rocket launches (See Figure 1-10).

Launch Area Number 5 - This is the launch site for the Vandal missile (See Figure 1-10). Vandal is a two-stage supersonic missile about 22 feet long and 30 inches in diameter. It is used as a target missile for off-shore Navy surface warship defense system tests. The dual launcher on this site will allow two vehicles to be configured, counted, and launched in a near salvo mode.

Dynamic Balancing Facility - The Dynamic Balancing Facility is used to balance rockets and large spacecraft. The facility consists of three buildings: V-45, V-50, and V-55 (See Figure 1-23). Buildings V-45 and V-55 contain dynamic spin balance bays, while Building V-50 contains the spin balance control rooms.

Rocket Motor Ready Storage, V-80 - This is located on the north end of the island (See Figure 1-10). It is 2,750 ft north of the Spin Balance facility, V-45, 2,500 ft from the coast, 450 ft from the coast road, and approximately 4,000 ft from the north end of the island. The entire 5,845 ft^2 facility is rated for, and used as, a hazardous storage facility (See Figure 1-24 and Figure 1-25). This facility is sited for 1.3 propellant.

Rocket Motor Storage, V-67 - This is a newly-constructed rocket motor storage facility at the north end of the island NE of V-80 and 4,000 feet from the Spin Balance facility. .(See Figures 1-25 and 1-26). This facility is sited for 1.1 propellant.

General Support Facilities/Areas - In addition to the above, there are multiple checkout, storage and assembly areas, a spin balance facility, and other support facilities and shops present on the island.

1.2.2 Local and Off-Range Instrumentation

This section contains detailed descriptions to include performance characteristics, coverage limits, and operating frequencies of the instrumentation systems generally used in the support of WFF launch operations.

1.2.2.1 Radar Systems

Radar systems track launch vehicles, sounding rockets, balloons, space vehicles, satellites, and aircraft to provide accurate velocity and position data. The range of support provided by radar systems at Wallops can vary from tracking local aircraft

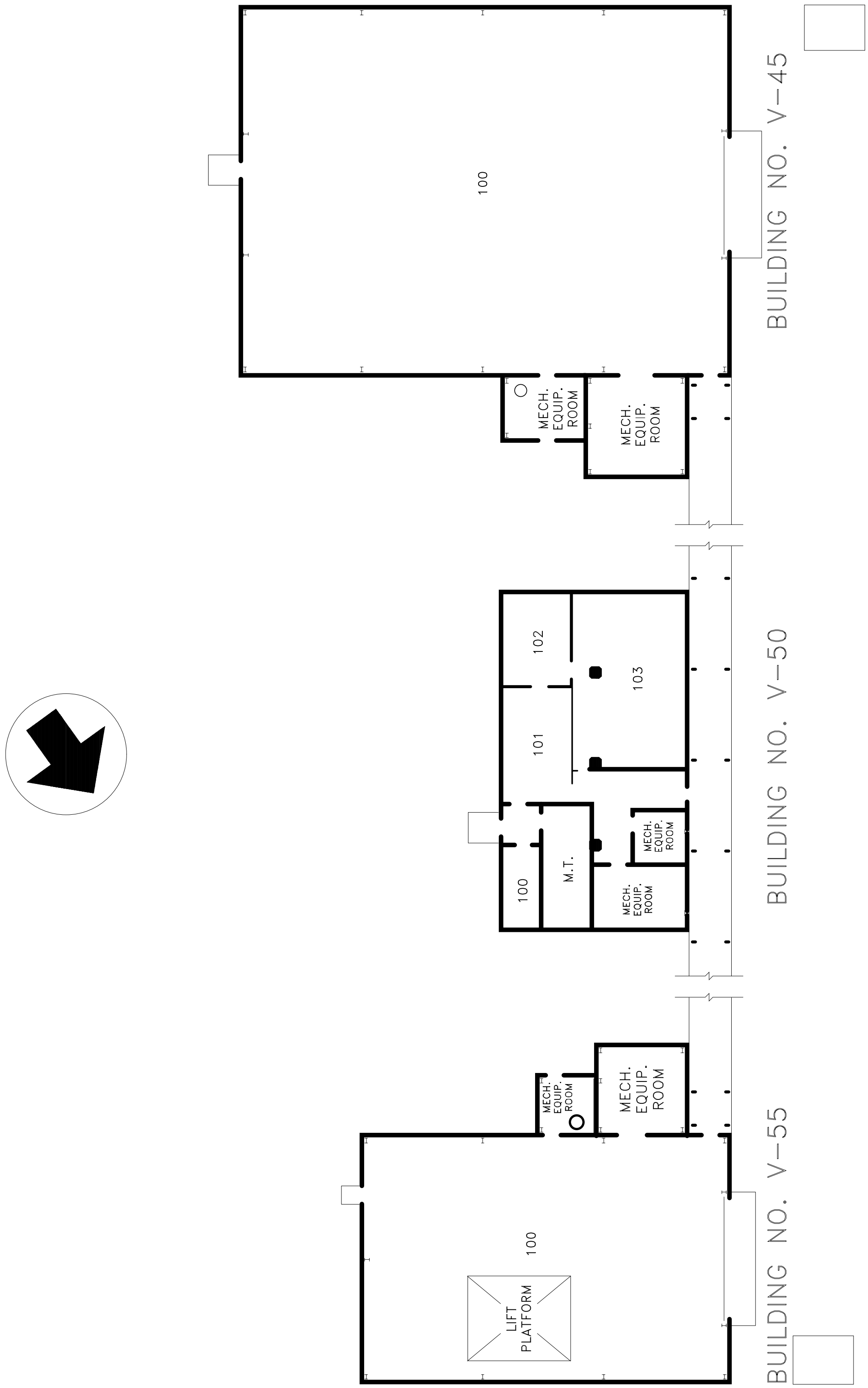


Figure 1 - 23: Building V-45, 50, and 55 Dynamic Balancing Facility

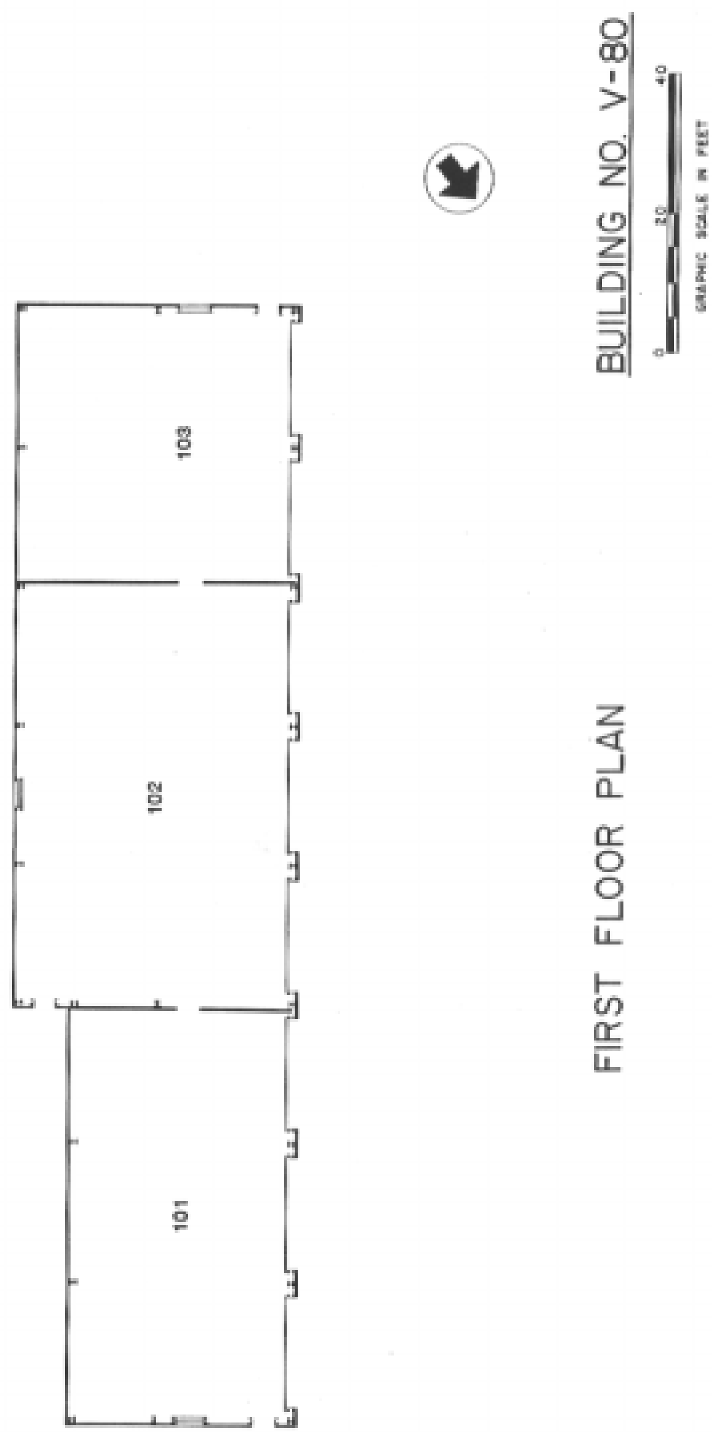


Figure 1 - 24: Building V-80, Rocket Motor Ready Storage

Figure 1 - 25: WFF Mainland and Island Test Range Launch Facilities

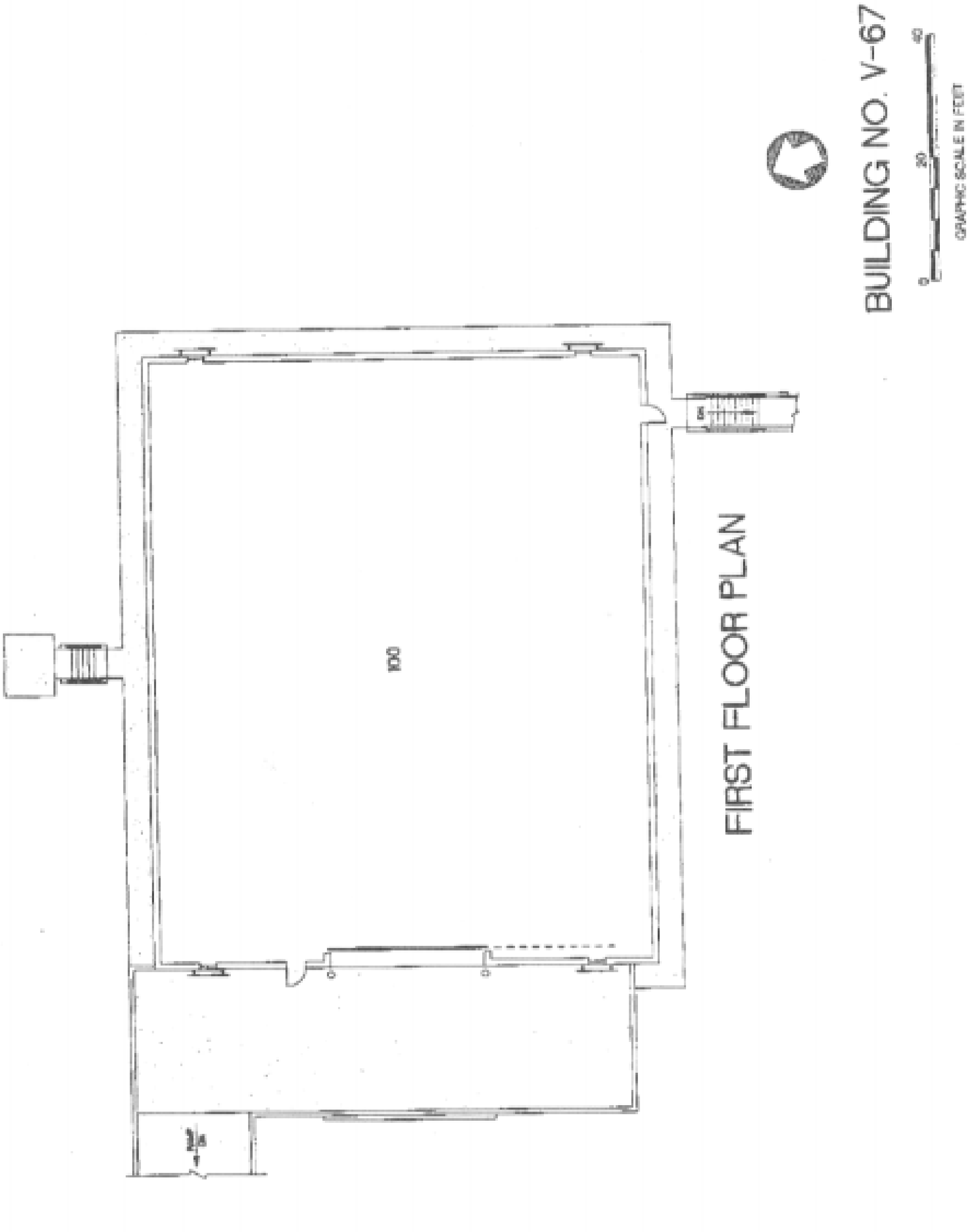


Figure 1 - 26: Building V-67, Explosive Storage Magazine

in the vicinity of Wallops airport to tracking distant objects in space. Radar capabilities can be enhanced by laser tracking systems and sophisticated data processing systems to improve the precision and to record, analyze, and process radar data. Radar performance characteristics, maximum range, and operating frequencies are shown in Tables 1-1, 1-2, and 1-3. The information provided in the following sections is representative of the support capability provided by WFF for commercial launch operations. Radar system resources are subject to change due to mission requirements, revisions and modifications and new technology.

Airborne Radar

Some Wallops Flight Facility aircraft are radar-equipped to support experiments and operations by providing range surveillance.

Fixed Radar

Island radars are located just south of the causeway. A C-band RIR-716 radar is located at building Y-55, while the X-band Mariner's Pathfinder radar is at building X-5 (see Figures 1-25 and 1-27).

Mainland radars are located on the mainland just south of the Wallops Island causeway. These radars consist of an FPQ-6, a UHF and an ASRF S-band SPANDAR. In addition, there is a C-band RIR-716 radar, which can be used to support launch operations, located at building A-41 (see Figure 1-28).

Additional radar systems from the Eastern Range resources are not normally used in support of WFF launches; however, they can be scheduled as necessary to support mission and safety requirements.

Mobile Radar

WFF operations can also be supported by mobile radars (identified in Table 1-2). A Mobile System (mobile RIR-778C) may be deployed to the Coquina site near Cape Hatteras, North Carolina, Bermuda or elsewhere worldwide.

Transportable Radar

A transportable RIR-778C is located at Poker Flat Research Range, Alaska (See Table 1-3 for specifications).

1.2.2.2 Photo Optical Systems

Still, video, and motion picture photography are available to support WFF activities and projects. Remotely-controlled television cameras monitor range operations and provide safety-related information. A processing/printing laboratory and limited video editing and reproduction facilities/capabilities are also available. See Table 1-4 and Figure 1-29 for optical system specifications and locations.

Table 1 - 1 WFF Airborne and Fixed Radar System Statistics

WFF ID No.	Radar	Wave Length Band	Peak Power Output (Watts)	Pulse Rate Frequency (pps)	Beam-width (deg.)	Antenna Size (Meters)	Antenna Gain (dB)	Max-Range (KM)	1-m² Skin Track (KM)	Range Precision (Meters) (rms)	Angle Precision (mils-rms)	Slewing Rates (deg/sec) AZ EL
UHF	ASRF	UHF	8M	320-960	2.9	18.29	36	n/a	1480	n/a	±2.0	8 8
4	ASRF (Spandar)	S	5M	1.603e+11	0.39	18.29	52.8	480K	2200	±5	±1.0	15 15
6	AN/MPS-19	S	325K	1.603e+12	3	2.44	33	925	100	±10 KMS	±1.0	60 60
n/a	AN-ASR-7	S	425K	713,1200 Others available	1.5(AZ) CSC² (EL)	5.33 x 2.74	34	110	75 (air-craft)	±1%	n/a	n/a n/a
5	AN/FPQ-6	C	3M	160,640 Others available	0.39	8.84	51	60K	1300	±3 rms	±0.05	28 28
3	RIR-716 (Island)	C	1M	160,640 Others available	1.23	3.66	43	60K	350	±3 rms	±0.1	45 28
18	RIR-716 Airport Radar	C	1M	1.606e+09	0.71	4.88	46	60K	435	±3.0	±0.1	45 25
18	Airport Laser	Infra-red	125	40	0.11	0.18	n/a	40	n/a	±0.5	±0.1	n/a n/a
n/a	Mariner's #2 Path finder	X	20K (Min)	9.002e+10	0.9@ 3 dB(H)	3.67 x 0.15	32	125	n/a	n/a	n/a	n/a n/a
n/a	AN/APS-80B (V)	9.2-9.6	200K	200	2.4 (H) 3.6 (V)	1.18 x 0.81	35	155	n/a	n/a	n/a	n/a
n/a	AN-MPS-128E	9.3	100K	2.674e+13	2.4 (H) 9.0 (V)	1.06 x 0.305	31	125	n/a	1% max. range	n/a	n/a

Table 1 - 2 WFF Mobile Radar System Statistics

WFF ID No.	Radar	Wave Length Band	Peak Power Output (Watts)	Pulse Rate Frequency (pps)	Beam-width (deg.)	Antenna Size (Meters)	Antenna Gain (dB)	Max-Range (KM)	1-m^2 Skin Track (KM)	Range Precision (Meters) (rms)	Angle Precision (mils-rms)	Slewing Rates (deg/sec) AZ EL
2	RIR-778C (mobile)	C	1M (Min)	160-320-640	3	2.38	38	3745	220	0.87204	0.2441	40 40
8	RIR-778C (mobile)	C	1M (Min)	160-320-640	3	2.38	38	3745	220	0.87204	0.2441	40 40
9	RIR-778C (mobile)	C	1M (Min)	160-320-640	3	2.38	38	3745	220	0.87204	0.2441	40 40

Table 1 - 3 WFF Transportable Radar System

WFF ID No.	Radar	Fre-quency (GHz)	Peak Power Output (Watts)	Pulse Rate Frequency (pps)	Beam-width (deg.)	Antenna Size (Meters)	Antenna Gain (dB)	Max-Range (KM)	1-m^2 Skin Track (KM)	Range Precision (Meters) (rms)	Angle Precision (mils- rms)	Slewing Rates (deg/sec) AZ EL
11	RIR-778C (transport able)	C	1M	160-320-640	3	3.66	43	60K	425	3.00	0.15	35 35

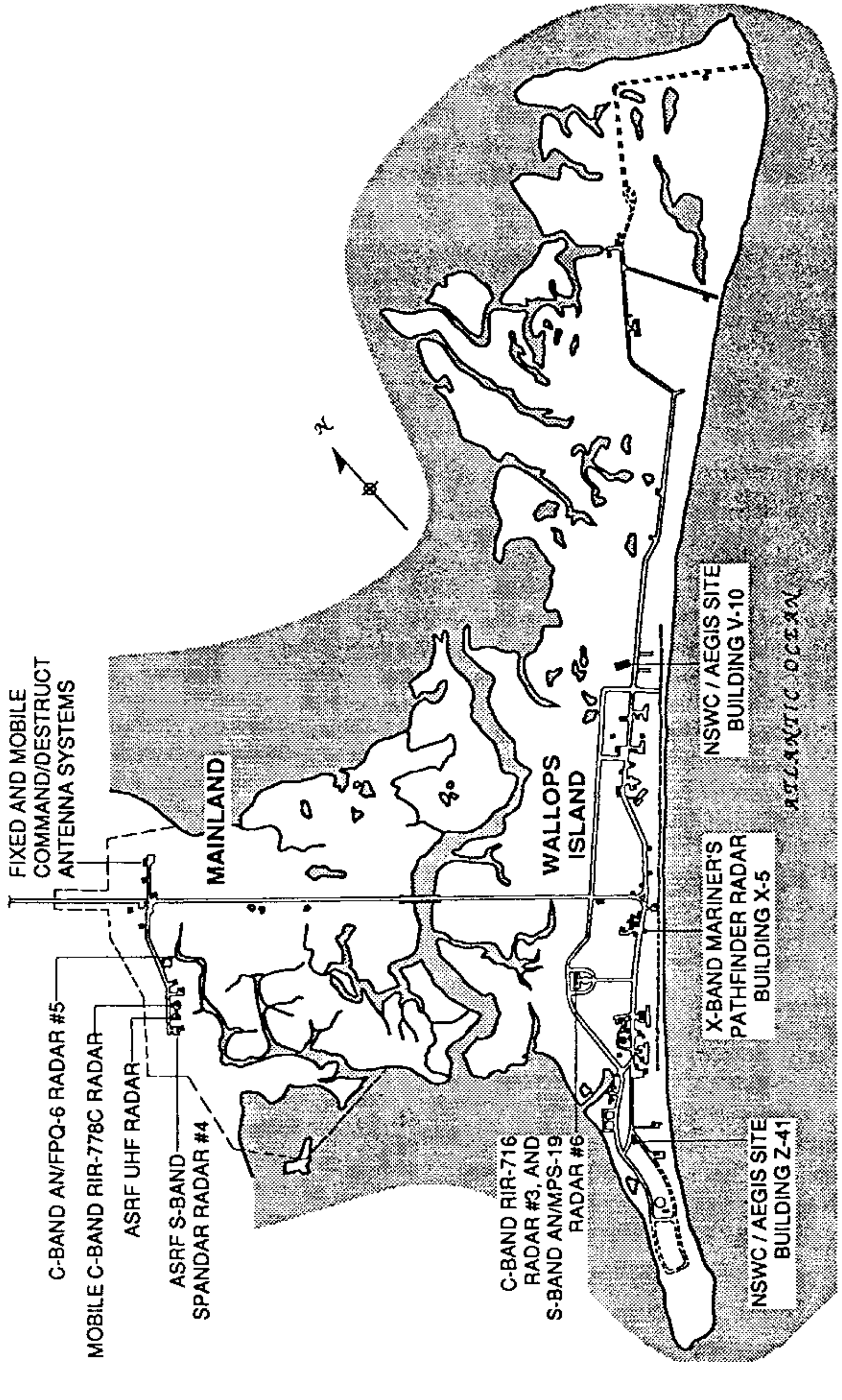


Figure 1 - 27: Wallops Island & Mainland Radar Sites, Mainland Command Sites

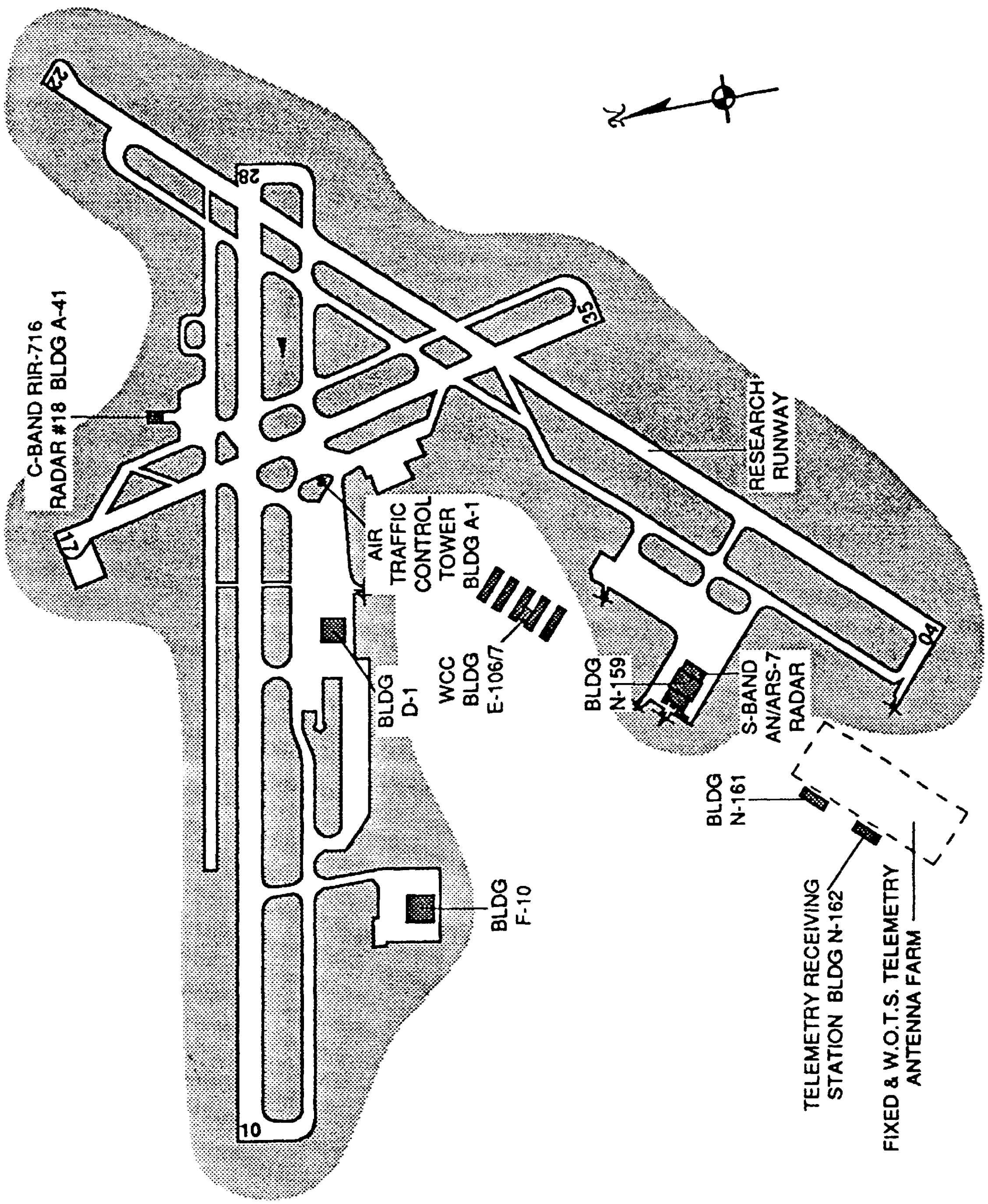


Figure 1 - 28: WFF Main Base Radar and Telemetry Sites

Table 1 - 4: Photo Optical Systems

ID No.	Station	System Type	Track Modes	Tracking Rates	Camera Type	Film Type	Lens Focal Length	Environmental Control
#1	Tracking	IFLOT Mk 1	EL/AZ Manual	22 deg/sec	MP Film	16-mm	40-inch 80-inch	12 foot Astrodome Shelter
#2	Tracking	SOT Mk 51	EL/AZ Manual	Manual	MP Film TV	16-mm Video	15-inch 12-inch	10 foot Astrodome Shelter
#4	Tracking	IFLOT Mk 3A	EL/AZ Manual	30 deg/sec	MP Film TV	16-mm Video	80-inch 40-inch	12 foot Astrodome Shelter
#5	Tracking	SOT Mk 51	EL/AZ Manual	Manual	MP Film TV	16-mm Video	10-20-inch ZOOM	10 foot shelter
#8	Tracking	IFLOT Mk 1	EL/AZ Manual	22 deg/sec	MP Film	16-mm	40-inch 40-inch	12 foot Astrodome Shelter
#9	Tracking	IFLOT Mk 3 (Mobile)	EL/AZ Manual	32 deg/sec	MP Film	16-mm	40-inch 80-inch	N/A
#11	Tracking	IFLOT Mk 1 (Mobile)	EL/AZ Manual	22 deg/sec	MP Film	16-mm	No Camera or Lens Assigned	N/A
#12	Tracking	IFLOT Mk 1 (Mobile)	EL/AZ Manual	22 deg/sec	MP Film	16-mm	6-to 80-inch	N/A
#15	Tracking	IFLOT Mk 3	EL/AZ Manual	32 deg/sec	MP Film TV	16-MM Video	80-Inch 80-Inch	12-foot Fixed Shelter
W-60	Fixed	Stationary Mount	Fixed	N/A	MP Film Sequence Film	16-mm 70-mm	12-mm to 12-inch 6- to 12-inch	10 foot Fixed Shelter
W-115	Fixed	Stationary Mount	Fixed	N/A	MP Film Sequence Film	16-mm 70-mm	12-mm to 12-inch 6-to 12-inch	10 foot Fixed Shelter
Y-110	Fixed	Stationary Mount	Fixed	N/A	MP Film Sequence Film	16-mm 70-mm	12-mm to 12-inch 6-to 12-inch	10 foot Fixed Shelter

IFLOT: Intermediate Focal Length Optical Tracker SOT: Short Range Optical Tracker MP: Motion Picture

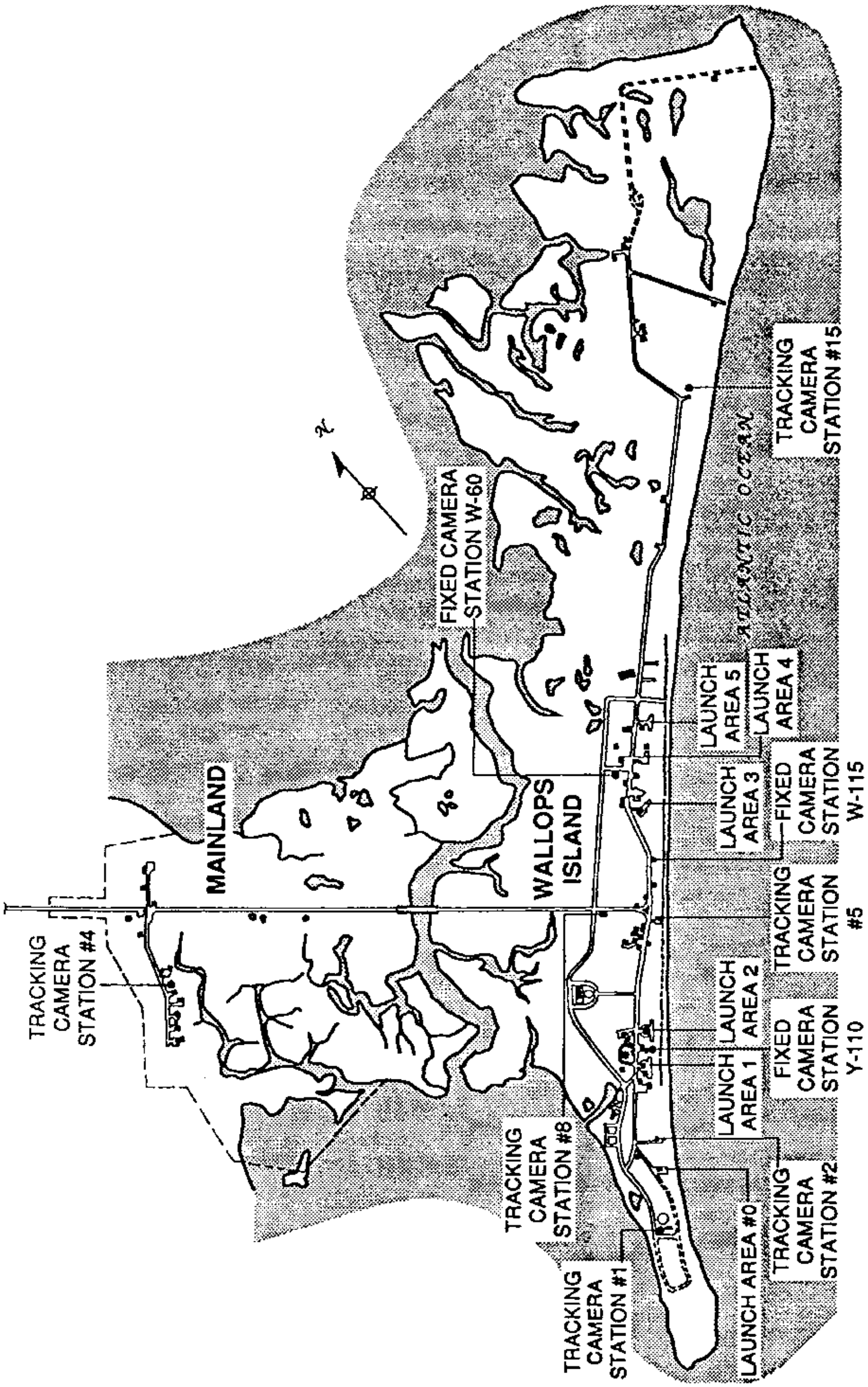


Figure 1 - 29: WFF Island and Mainland Optical Tracking Stations

Tracking and Fixed Camera Stations

Tracking and fixed cameras, including both film and a long-range video tracking system, provide visual information from island locations primarily for support of rocket and balloon launches.

Mobile Systems

Mobile tracking camera equipment can be transported to remote sites to provide required support.

Aerial Platforms

Still, motion picture, and video cameras can be installed on several WFF aircraft

1.2.2.3 Telemetry Systems

WFF has fixed and transportable telemetry systems/facilities to be used in support of rocket launches and low earth orbit spacecraft. Where experiments employ multiple RF carriers, selection of a carrier for tracking purposes is a range user's option, since it does not impinge on the reception of telemetry data. The fixed-receiver system offers the range user a high degree of flexibility and redundancy. Each of two identical systems contains six receivers with plug-in RF heads to cover the appropriate frequency band. All systems can receive multiple links over a broad frequency spectrum. Telemetry system specifications are included in Tables 1-5 through 1-9. The information provided in the following sections is representative of the support capability provided by WFF for commercial launch operations. Telemetry system resources are subject to change due to mission requirements, revisions and modifications and new technology.

Fixed Telemetry Systems

Multiple independently controlled telemetry antenna systems are located on the WFF Main Base near the approach to runway 04 (See Figure 1-28). These systems are controlled from the fixed range telemetry facilities and Wallops Orbital Tracking Station (WOTS), which are co-located in building N-162. An expanded view of the Mainland telemetry area is shown in Figure 1-30 and an aerial view appears as Figure 1-31. WOTS primarily supports low earth orbit spacecraft; however, its facilities are flexible enough to support range telemetry. In fact, WOTS shares resources with the range telemetry systems. It capabilities include both metric tracking and command uplink. (See Tables 1-5, 1-7, and 1-9 for specifications).

Table 1 - 5: Range Telemetry Systems (Fixed)

RECEIVING CHARACTERISTICS

Antenna Type/Dia	Frequency Range	Polari-zations	Noise Temp @ Degrees K	Receiver type	Gain	Tracking Modes	Pedestal Type
(1)Fixed Dish LGTAS 2.4M/8 ft	1435-1540 MHz 1650-1710 MHz 2200-2300 MHz	RHC/LHC	400 @ S-Band	Microdyne 1100-AR	L-Band: 28 dB 1680 Band: 29 dB S-Band: 32 dB	Autotrack Slave Manual Computer	EL/AZ
(2)Fixed Dish MGTAS 7.5M/24 ft	1400-2400 MHz	RHC/LHC	200 @1.4-2.1GHz 250 @2.2-2.3GHz	MFR S/A 410 DEI 74 Microdyne 1100-AR	39 dB @ 2250 MHz	Autotrack Slave Manual Programmed	EL/AZ

TRANSMITTING CHARACTERISTICS

Antenna Transmitter

Type/Dia	Freq. Range	Polarizations	Type	Power	Gain	Tracking Modes	Pedestal Type
(1)Fixed Dish LGTAS 2.4M/8 ft.	547 & 550 MHz	RHC	FM	30W	10 dB	Autotrack Slave Manual	EL/AZ

Notes:
1. The Low Gain Telemetry Antenna System (LGTAS) antennas reside atop Building N-162.
2. Medium Gain Telemetry Antenna System (MGTAS) is located in antenna field near building N-162. The MGTAS is also part of the WOTS system.
3. The WOTS 18M antenna system can be used for GSFC/WFF range support upon request. For data on 18M see Table 1-7.

Table 1 - 6: Mobile/Transportable Telemetry Systems Summary

Antenna Type/Dia.	Frequency Range	G/T (Minimum)	Tracking Modes	Pedestal Type	Trailer	Van	Remarks
Antenna #1 (M) 3M/10 ft 4 Section Parabolic	215-260 MHz 1435-1540 MHz 1650-1710 MHz 2200-2300 MHz	7.1 dB/K @ 2.25 GHz	Autotrack Slave Manual	EL/AZ	8.5M/28 ft Lowboy	Can be used with Van #1 (RV) and Van #2	Shipping container available; color, green.
Antenna #2 (M) 3M/10 ft Solid Parabolic	215-260 MHz 1435-1540 MHz 1650-1710 MHz 2200-2300 MHz	7.1 dB/K @ 2.25 GHz	Autotrack Slave Manual	EL/AZ	8.5M/28 ft Lowboy	Can be used with Van #1 (RV) and Van #2	Shipping container available; color, blue.
Antenna #3 (M) 2.4M/8 ft Solid Parabolic	1435-1540 MHz 2200-2300 MHz	5.18 dB/K @ 2.25 GHz	Autotrack Slave Manual	EL/AZ	5.5M/18 ft Lowboy	Can be used with Van #1 (RV) and Van #2	Antenna #3 is referred to as the "old 8-footer." Shipping container available; color, gray.
Antenna #4 (M) 2.4M/8 ft Solid Parabolic	1435-1540 MHz 2220-2300 MHz	5.18 dB/K @ 2.25 GHz	Autotrack Slave Manual	EL/AZ	5.5M/18 ft Lowboy	Can be used with Van #1 (RV) and Van #2	Antenna #4 is referred to as the "new 8-footer." Shipping container available; color, white.
Antenna #5 (M) 2.4M/8 ft Solid Parabolic Reflector	1435-2300 MHz (includes 1680)	5.18 dB/K @ 2.25 GHz	Autotrack Slave Manual	EL/AZ	n/a	n/a	Installed at Poker Flat Research Range
Antenna #6 (M) 2.4M/8 ft Solid Parabolic Reflector	1435-2300 MHz (includes 1680)	11.0 dB/K @ 2.25 GHz	Autotrack Slave Manual	EL/AZ	n/a	n/a	Installed at Poker Flat Research Range
Antenna #7 (M) 2.1M/6ft "Minitracker" 2 Section Parabolic	2200-2300 MHz	2.9 dB/K @ 2.25 GHz	Autotrack Slave Manual	EL/AZ	n/a; compact pedestal	n/a	Minitracker TM Systems can be shipped via nine boxes weighing 1000 lbs. (6.3675M/225 cu ft).
Antenna #8 (M) 2.1M/6ft "Minitracker" 2 Section Parabolic	2200-2300 MHz	2.9 dB/K @ 2.25 GHz	Autotrack Slave Manual	EL/AZ	n/a; compact pedestal	n/a	Minitracker TM Systems can be shipped via 9 boxes weighing 1000 lbs. (6.3675M/225 cu ft).
Antenna #9 (M) 6.1M/20ft 8 Section Mesh Parabolic	1435-1540 MHz 2200-2300 MHz	17.2 dB/K @ 2.25 GHz	Autotrack Slave Manual	EL/AZ	12.8M/42 Flatbed with an enclosed shelter	#4	Antenna #9 can be shipped in a C-141 aircraft.
Antenna #10 (M) 5.5M/18 ft 16 Section Mesh Parabolic	1435-1540 MHz 2200-2300 MHz	14.5 dB/K @ 2.25 GHz	Autotrack Slave Manual	EL/AZ	n/a	Self-equipped container	Antenna #10 is configured for shipborne transport.
Antenna #11 (T) 8M/26 ft Sectioned Solid Parabolic	2200-2400 MHz	xx dB/K @ 2.25 GHz	Autotrack Slave Manual Program	EL/AZ	ISO Container 2 each 13M/43 ft	20-ft van	Can be shipped by C-141 or sea and truck.

Table 1 - 7: Transportable Orbital Tracking Station (TOTS) Systems

Receiving Characteristics

Antenna Type/Dia.	Frequency Range	Polarization	G/T (Minimum)	Receiver Type	Up/Down Con. Frequency	Tracking Modes	Pedestal Type
Transportable system 8M/26ft Parabolic	2200-2400 MHz Upper L-Band	RHC & LHC Diversity Combined Pre/Post Detection	150° K; 21 dB/° K G/T	S/A 930; Microdyne 1400; Microdyne 1100; MFR, DEI 7400	Raw; 215-315 MHz 400-500 MHz	Auto; Manual; Slave; Computer	S/A 3315M; EL/AZ; 20°/Sec AZ/EL Velocity; 20°/sec AZ/EL Acceleration

Transmitting Characteristics

Antenna Type/Dia.	Frequency Range	Polarizations	Transmitter Type	Power	Tracking Modes	Pedestal Type
Helix 10 Turn	547, 550, 553 MHz	RHC	Various Typese	200W RMS for 63 dBmi	Auto; Manual; Slave Computer	S/A 3315M; EL/AZ: 20°/Sec AZ/EL Velocity; 20°/Sec AZ/EL Acceleration
Transportable System 8M/26 ft Parabolic	2025-2120 MHz	RHC or LHC	AYDIN Solid State	200W RMS for 93 dBm EIRP @ 2025 MHz	Auto; Manual; Slave Computer	S/A 3315M; EL/AZ: 20°/Sec AZ/EL Velocity; 20°/Sec AZ/EL Acceleration

NOTES:
1. TOTS requires pre-positioned concrete pad for precision angular accuracy.
2. Housed in a 40-foot expanding-side ISO container.
3. Set-up time is estimated to be three days after arrival on site.

Table 1 - 8: Transportable Van/TM System Summary

VAN	SIZE	FUNCTION
Van #1 8M/26 ft RV	7.9m (26 ft)	This is a self-propelled recreational research vehicle equipped to support various balloon programs. It is a modified GMT Transmode Van; gross wt of 4540 kg (10,000 lbs). Interfaces with Scientific Atlanta 2.4 m (8 ft) & 3.3 m (10 ft) tracking antennas.
Van #2 12M/40 ft expandable trailer	12.2 m (40 ft)	Largest expandable instrumentation van (trailer) at Wallops that features automatically regulated air suspension sysstem for leveling and shock protection. Antenna controls for 2.4 m (8 ft) & 3.3 m (1o ft) dishes are installed in this trailer. Two additional vans with similar characteristics are being procured.
Van #3 12M/40 ft trailer	12.2 m (40 ft)	Standard 40 ft trailer used on various mobile campaigns with same capabilities as Van #2, less antenna controls.
Van #4 12.5M/42 ft trailer w/shelter	12.2 m (40 ft)	Specially equipped to provide full range control support at remote sites worldwide for the 6 m (20 ft) antenna system.
Self-equipped	3.3 m (10 ft)	Supports Mini-tracker system.
Pad-mounted	Various	Equipped to support pad mounted 8 m (26 ft) TM antenna.

Table 1 - 9: Wallops Orbital Tracking Station (WOTS)

Receiving Characteristics

Antenna Type/Dia.	Frequency Range	Polarizations	G/T (Minimum)	Receiver Type	Up/Down Con.Freq.	Tracking Modes	Pedestal Type
Parabolic Fixed dish 18M/60ft	1.4-2.4 GHz	LHC & RHC div	28.5 db/K@ 2.2-2.4 GHz 28 db/K @ 1.4-2.4 GHZ	MFR	400-500 MHz P-Band	Manual, auto, STAR and STPS (future)	EL/AZ
Parabolic Fixed dish 9M/30ft	2.2-2.3 GHz	RHC & LHC div	23 db/K@ 22250 MHz	MFR	400-500 MHz	Auto, slave, TDPS, manual, and STPS (future)	X-Y
Parabolic Fixed dish S/A 7.3M/24 ft (STDN) 2 each	1.4-2.4 GHz	H/V or LHC & RHC div	16 db/K@ 2.2-2.4 GHz 13 db/K @ 1.4-2.4 GHZ	MFR, S/A 410 DEI 74, 1100-AR	400-500 MHz P-Band	Auto, slave, manual, programmed	EL/AZ
Fixed Array 1 SATAN	136-138 MHz	Linear Diversity	-8 db/K@ 137 MHz	MFR	400-500 MHz	Manual, slave	X-Y
Fixed Array 2 SATAN	136-138 MHz	Linear Diversity	-8 db/K@ 137 MHz	MFR	400-500 MHz	Manual, slave	X-Y
Parabolic Fixed dish (dedicated) METEOSAT/ 7.3M/24ft	1690-1700 MHz	Linear Diversity	19.6 db/K@ 1690 MHz	1100-AR	400-500 MHz	Manual	EL/AZ Kingpost
Parabolic Fixed dish 7.3M/24ft UHF	464-469 MHz	RHC & LHC div	4.0 db/K@ 466 MHz	MFR	none	Manual, slave	X-Y

Transmitting Characteristics

Antenna Type/Dia.	Frequency Range	Polarizations	Transmitter Type	Power	EIRP	Tracking Modes	Pedestal Type
Fixed dish 9M/30ft	2025-2120 MHz	RHC/LHC	TWTA/exciter Solid State Amp	200 W/16 W	96 dBmi	Auto, slave TDPS, manual, and STPS (future)	X-Y
Fixed dish 6M/20ft Command	2025-2120 MHz	RHC/LHC	TWTA/exciter Solid State Amp	200 W/16 W	92 dBmi	Manual, slave	X-Y
Fixed Array SATAN	147-152 MHz	RHC/LHC Linear	Linear	10 KW	92 dBmi	Manual, slave	X-Y
Fixed Array SCAMP	147-152 MHz	RHC/LHC Linear	Linear	10 KW	87 dBmi	Manual, slave	X-Y

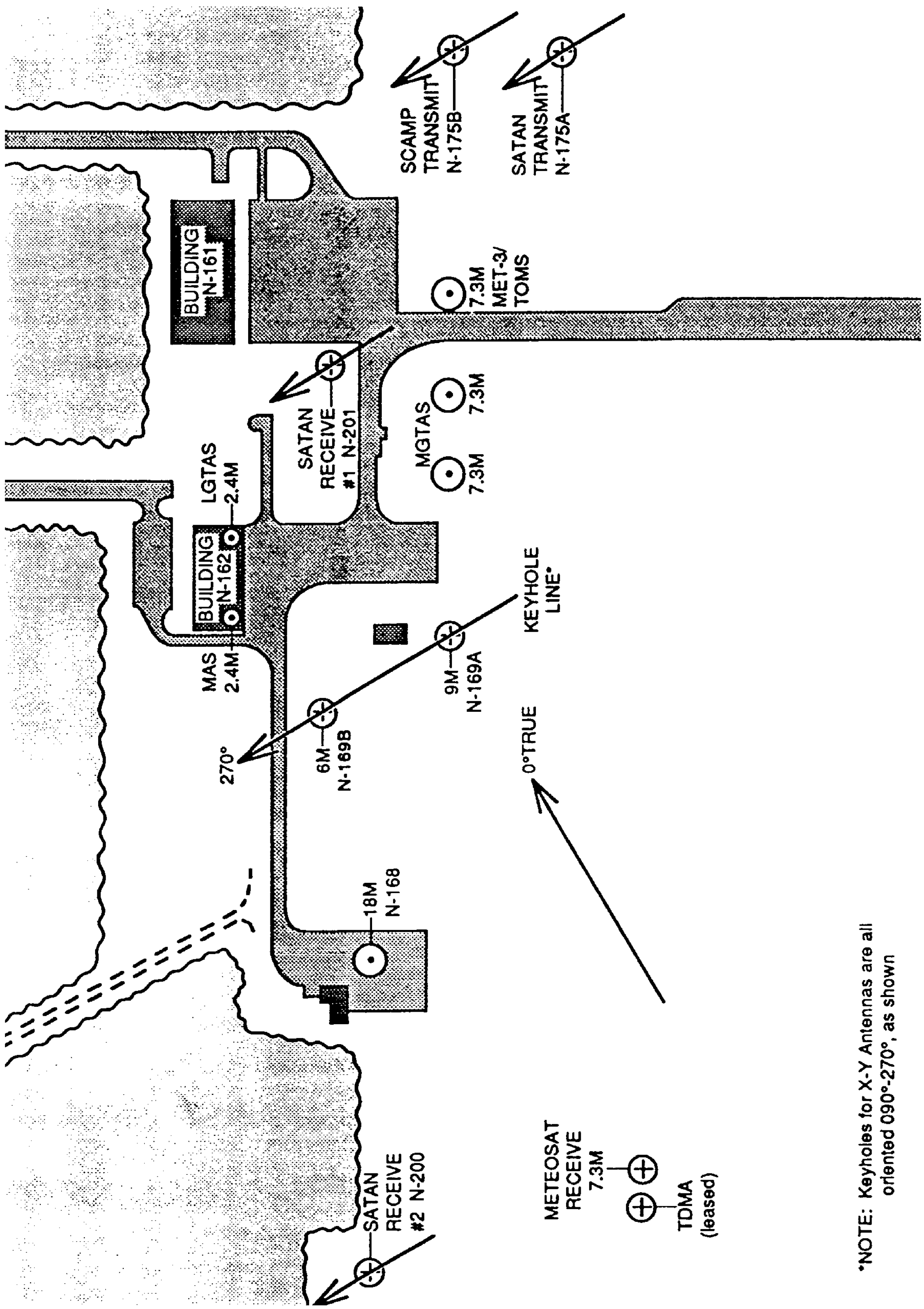


Figure 1 - 30: Fixed TM & Wallops Orbital Tracking Station Antenna Farm

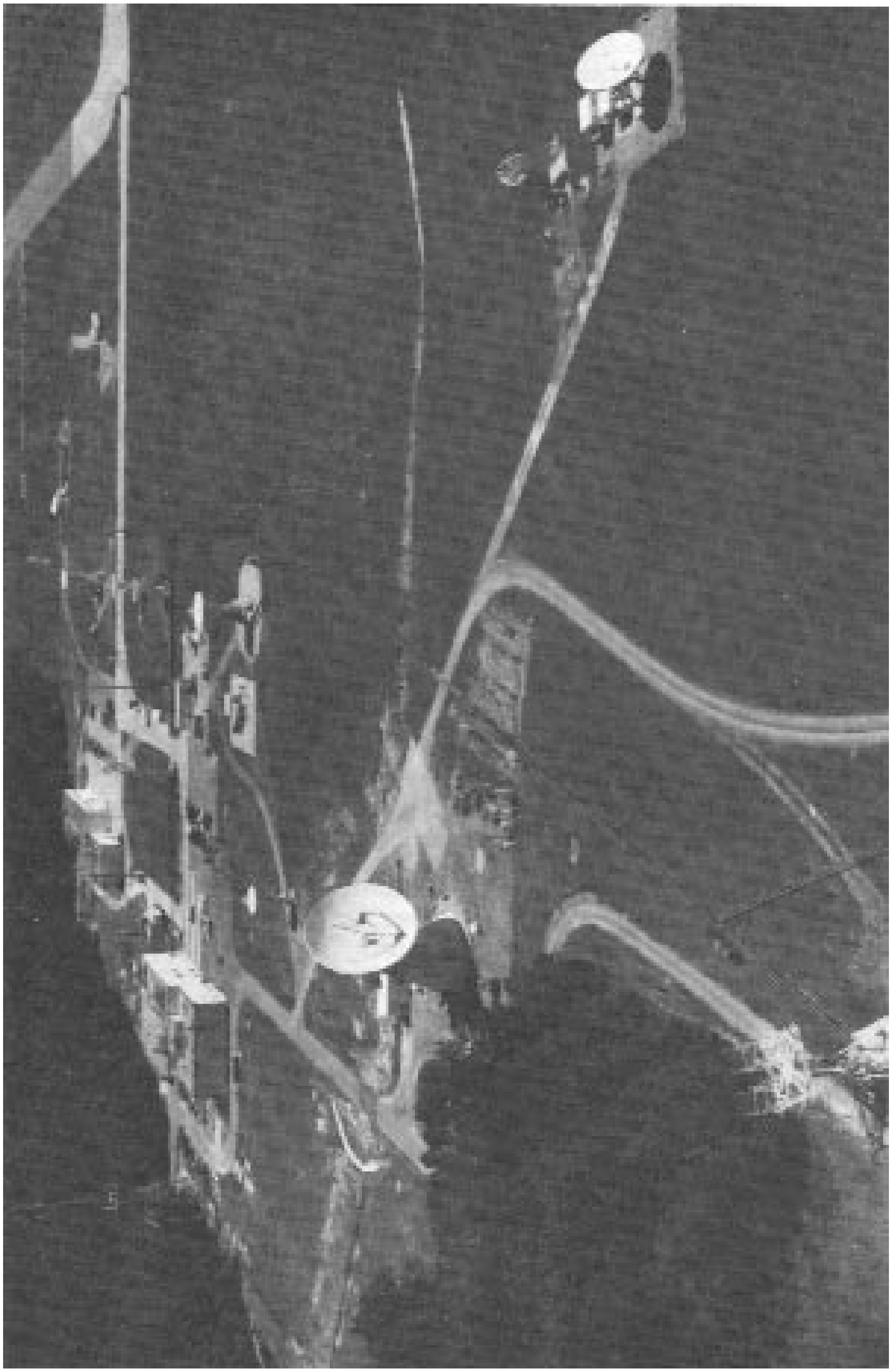


Figure 1 - 31: Range Telemetry Facility and Wallops Orbital Tracking Station (WOTS)

Mobile Telemetry Systems/Facilities

Mobile telemetry systems are designed to achieve rapid and simple installation in the field without permanent site preparations. Antenna types 1-10, Table 1-6, fit in this category. Additional details on Mobile systems are covered in section 1.2.2.6.3.

Transportable Telemetry Systems/Facilities

Transportable telemetry systems are designed to provide temporary coverage at locations beyond that served by fixed facilities at Wallops. These systems require some permanent site preparation. Antenna types 11, 12, and 13 are in this category. These systems have metric tracking (Doppler and angles) and command uplink capabilities. The Transportable Orbital Tracking Station (TOTS) Systems were developed to provide multimission transportable low earth orbit spacecraft tracking capability. However, TOTS can also support vehicle and payload telemetry. Currently there are three fully automated TOTS systems. One is installed at Poker Flat Research Range. Tables 1-6 to 1-8 list the transportable systems specifications. Figure 1-32 shows a system configured for support.

Figure 1 - 32: Transportable Orbital Tracking Station (TOTS)

1.2.2.4 Communication Systems

WFF operates ground-to-ground, ground-to-air, air-to-ground, ship-to-shore, range intercom, and intra-station communications systems. These systems are composed of HF/VHF/UHF radios, cables, microwave links, closed-circuit television systems, command and control communications, frequency shift tone keying systems, high-speed data circuits, and the WFF NASCOM Network terminal. The cable plant supporting these communications systems includes extensive telephone, coaxial cable, and fiber optics cables interconnecting the WFF facilities. Fiber optic cables are used to connect the Main Base, Mainland and Wallops Island areas.

Communications provide the means for managing operations at Wallops and communicating and coordinating operations with related operations in other geographic areas (e.g., ER, WR, Alaska). These communications systems are located at Wallops Island, Wallops Mainland, and Wallops Main Base, at remote stations, and mounted in vans for downrange and shipboard use. RF support services include spectrum management, frequency monitoring and interference control, search, recovery and homing systems, and meteorological information systems.

The Communications Receiver Facility is located on the Main Base in the Telecommunication Building (N162 in Figure 1-31), which houses the receivers, recorders, patching panels, command/destruct monitors and recorders, and the supporting ancillary equipment.

The receiving antennas are mounted on towers and poles in the immediate area. Worldwide reception is possible. The Frequency Monitoring and Interference Control facilities are co-located with the Communications Receiver Facility.

The Communications Transmitter Building is located just to the north of and inside the mainland entrance to the island facility. The transmitting antennas are mounted on top of the building and on towers and poles in the immediate area. An auxiliary power generator for the redundant command/destruct and communications systems is located in an adjacent building at this facility.

1.2.2.5 Command Destruct Systems

Ground-based Command Destruct Systems provide ground control of certain rocket and payload functions for flight safety and/or other command purposes. The range user can use these systems to command payload functions, as necessary, within range limitations.. The information provided in the following sections is representative of the support capability provided by WFF for commercial launch operations. Command system resources are subject to change due to mission requirements, revisions and modifications and new technology.

Fixed Command Destruct Systems

These systems are located just to the north of, and inside, the Mainland entrance to the island facility (See Figure 1-27). Each permanent system consists of two Radio Transmitting Sets with omni-directional and single-helix as well as quad-helix antennas. Each transmitter has an RF power output of ~1000 watts in the frequency range of 406.0 to 549.0 MHz. There are two fixed command systems located on the Mainland. These systems provide command coverage until impact, orbital insertion, or the vehicle no longer endangers the public. An electronic switch between the WFF active command site and the Bermuda command site occurs at a predesignated time or elevation angle. This handover allows the safety officer to maintain control of the vehicle to the extent required by the mission rules. Rockets and payloads up to those in low earth orbit can be effectively commanded if they are within line-of-sight of the transmitter.

A fixed system (See Table 1-10) consists of two subsystems connected in a fail-over arrangement. If the primary subsystem fails, or if the RF power output falls below a predetermined level, fail-over is automatically initiated. The redundant subsystem then assumes control of the Command/Destruct function.

Table 1 - 10: Wallops Fixed Command/Destruct Systems

Transmitters			Antennas		
Type	Frequency	Power	Type/Control	Gain	Polarization
(2)ALEPH CTS-100 1000 Watts	406-549 MHz FM IRIG Tones	*Commercial AC *Generator for redundant system	(2)Orbit quad-helix, radar slaved or manual control	18 dB	LHC
			(2) Omni	0 dB	Vertical

Primary Command/Destruct Subsystem - The Primary Command/Destruct Subsystem consists of an ALEPH CTS-100 Transmitting Set, an ANTLAB Quad-helix antenna and the necessary control circuits. The transmitter modulation can be controlled locally, or by remote control from the WICC. The transmitter and the antenna pedestal operate from commercial AC power. The primary antenna is slaved, by means of the radar data acquisition bus, to a radar selected to provide the most accurate position information on the rocket/payload being tracked.

Redundant Command/Destruct System - The Redundant Command and Destruct Subsystem (identical to the primary) is powered by a local generator so that, in case of a failure of commercial power during a mission, control will still be maintained over the rocket/payload. The Quad-helix antenna used with this subsystem is positioned manually using predetermined angle versus time information.

Mobile Command Destruct

The function of a mobile command destruct system is the same as a fixed system. The mobile systems are used to extend the range to accomplish required mission objectives or to establish a mobile range for launch support where there would otherwise be none. For example, a Mobile System may be deployed to the Coquina site near Cape Hatteras, North Carolina, to the Poker Flat Research Range, or to an alternate site as required by the mission. There are two redundant mobile command systems that are each a part of a mobile range support system. The first system is the Mobile Range Control System (MRCS), which includes two Power Systems Technology 1000W Transmitters with Marconi exciters mounted in a C-130 container. The second is the Mobile Command Destruct System (MCDS), which includes two Henry Radio Company 1000W Transmitters and Marconi exciters mounted in a 20 foot trailer. This system supports launches in instances where all of the functions of a mobile range safety system are not required. Both systems can be transported by air, rail, or ship. They both will be discussed in more detail in the following section on Mobile Systems.

1.2.2.6 Mobile Systems

WFF has the capability to support launch campaigns at locations outside of the WFF range (worldwide). Mobile systems have been developed and used to provide radar, telemetry, command destruct, range safety displays and command and control functions in support of both suborbital and orbital missions. The predecessor to the MCDS was used at Poker Flat Research Range in support of *sounding rocket (AF Talos M6 launches) as well as the Minisat mission from the Canary Islands.* The new (1996) mobile system consists of the MRCS trailer (mobile range control), a Telemetry Van (downlink data from the launch vehicle), and a Radar Van (launch vehicle tracking data). Figure 1-33 shows a line art drawing representative of the mobile configuration. The exact configuration depends on the launch user requirements and safety considerations as well as the launch site location, vehicle characteristics, and flight profile. The following paragraphs provide greater detail on the individual components that comprise a mobile system.

1.2.2.6.1 Mobile Range Control System Trailer

The WFF Mobile Range Control System, developed and upgraded in 1996, is enclosed in a 48 ft. C-131 container (see Figure 1-34). It contains a display system identical to the system in the Wallops Integrated Control Center. This new display system is part of the "mobile range safety real-time instantaneous impact prediction system" (MRTIIPS) (see Figure 1-35). As the figure shows, the MRTIIPS is actually three consoles in one. Each section, IIP#1, data quality control console (DQC), and IIP#2, is approximately six feet long. The overall system is nearly 20 ft long. During operations, two operators will sit at each of the three consoles.

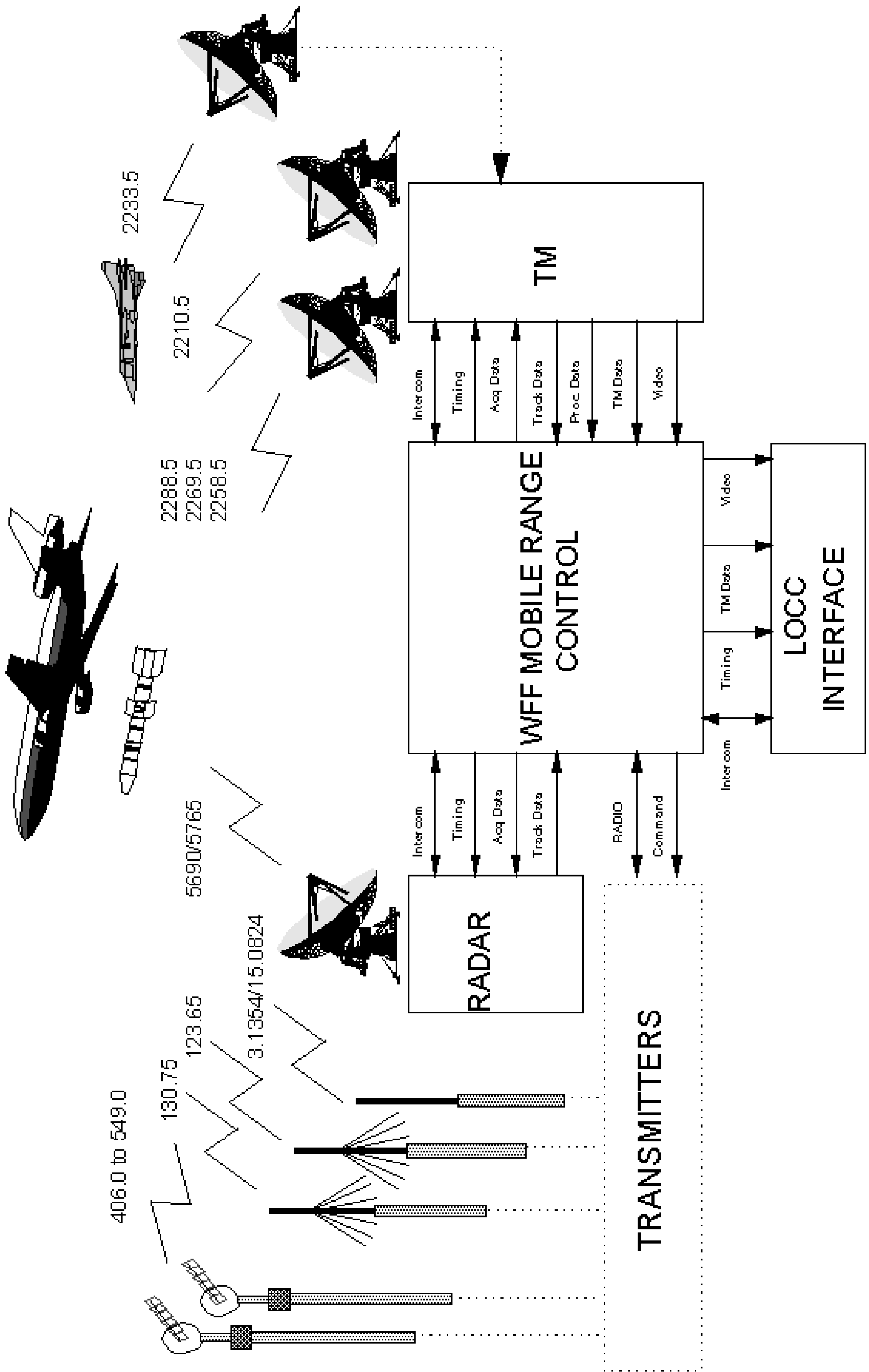


Figure 1 - 33: WFF Mobile Instrumentation Configuration

Figure 1 - 34: Mobile Range Control System

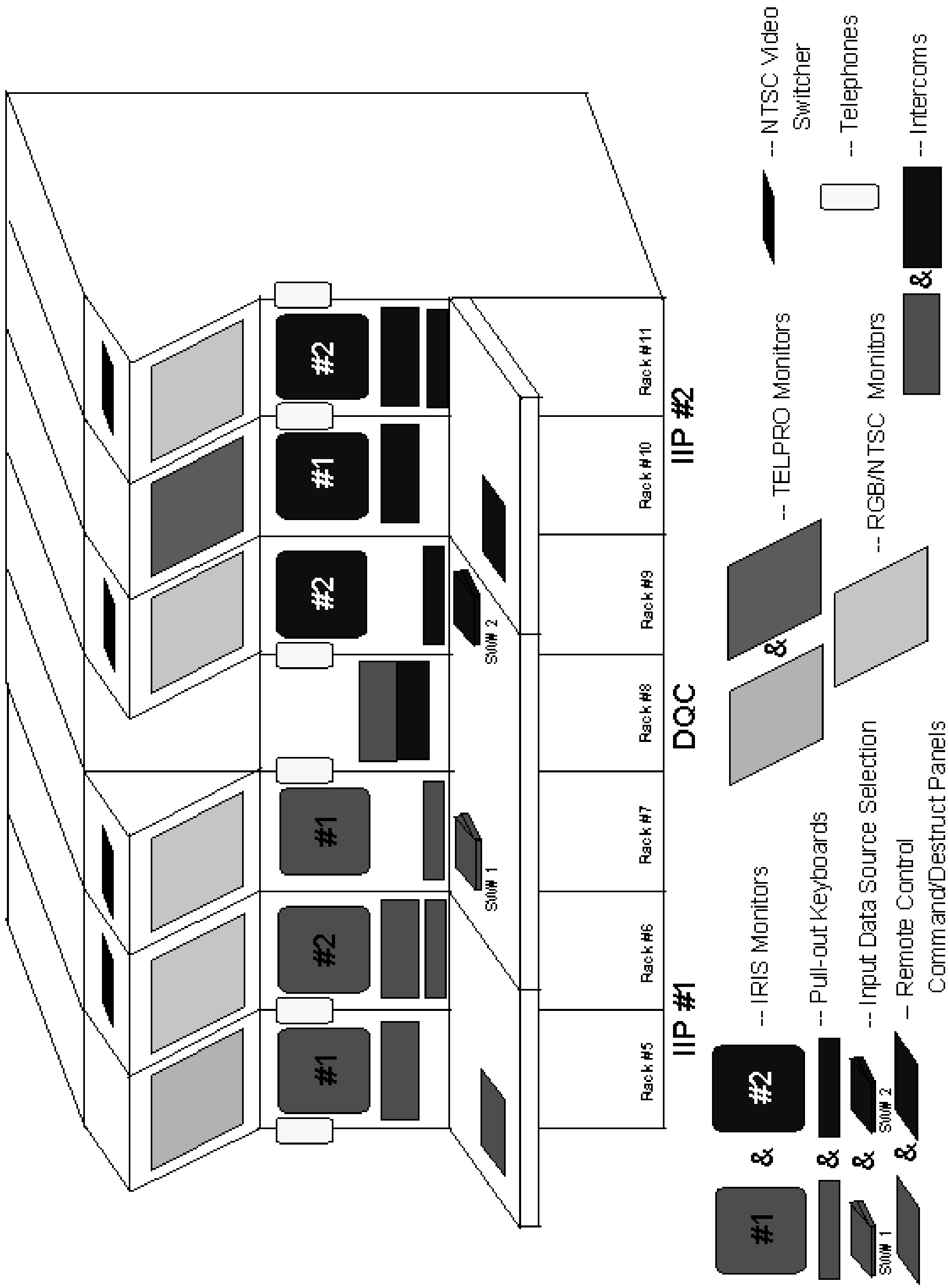


Figure 1 - 35: Mobile Range Safety Real Time Instantaneous Impact Prediction System

The following description is an example of how the display systems may be used, actual use varies from mission to mission depending on specific requirements. IIP#1 and IIP#2 are identical, independent console systems with #1 designated as prime and #2 as backup. The entire missile flight safety mission could be accomplished from either console. The panels on the shelves of IIP#1 and IIP#2 contain the arm and destruct buttons and the monitoring system for the missile flight destruct system. On the inclined portion of these consoles are the intercom control panels bounded on each side by a telephone. The six displays on the vertical surfaces are Iris displays. The vertical displays labeled #1 on both of the IIP consoles are identical in what is programmed as output. Both show multi-scale IIP trajectory data in the plus count. The #1 Iris display on both consoles may also show orbital prediction data after orbital insertion stage burnout. This display shows whether the vehicle is capable of reaching orbit, based on the burnout parameters and the known trajectory data. The #2 vertical displays on both IIP consoles can be switched to one of four different display formats.

During the plus count, the #2 display on IIP#1 may show nozzle pressure versus time or pitch and yaw versus time. During pre-mission support, this display may show flight termination system (FTS) data, safe and arm system status, link data, command receiver battery voltage, and AGC levels. The #2 display on IIP#2 may show velocity versus time, altitude versus ground range, flight elevation angles versus flight azimuth angles, or present position data, e.g., latitude and longitude, and altitude versus ground range. The six monitors located across the top of the system are 11 inch video monitors. The leftmost on IIP#1 is fed by TELPRO #1 and the leftmost on IIP#2 is driven by TELPRO #2 (see the Telemetry section for an explanation of the TELPRO systems). The right hand display on each IIP console is configured to show channels of switched video.

A video presentation of the TELPRO PC system data and additional telemetry data are also displayed on the center DQC. User PC data (normally telemetry), inertial navigational system (INS) state vector data, and Global Positioning System (GPS) satellite data are also displayed on the video monitors on the center console. Available GPS data includes the number of satellites being tracked, state vector timing information, and the health and status of the GPS system. On the DQC console, the switches SW#1 and SW#2 control which real-time sources are available for display. Switch #1 controls the IBM Master computer #1 and switch #2 controls IBM Master computer #2. The inclined panel on the DQC houses the video switch panels that control the output to the video displays on all three consoles.

Figure 1-36 is a flow diagram for the MRTIIPS. The top section of the figure identifies the flow of data and timing into and out of the telemetry computers and displays. The subsequent blocks identify the flow of data and timing to/from IIP System #1, the DQC console, IIP System #2, and their related real-time computers and display systems. Inputs to IIP System #1 are first fed to the IBM Master

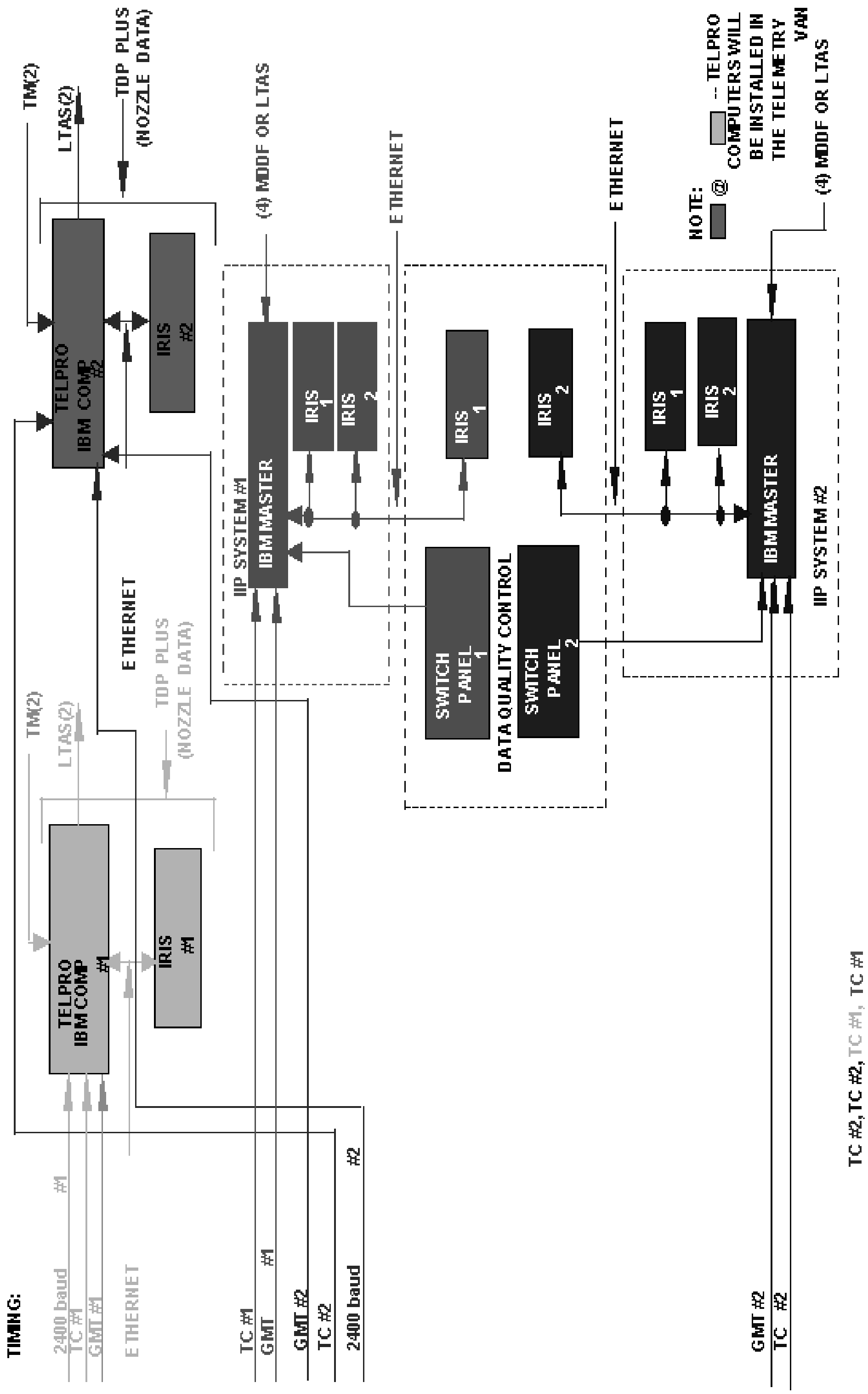


Figure 1 - 36: Timing and Data Flow for MRTIIPS

computer #1. These inputs include Time Code Generator (TCG) #1, Greenwich Mean Time (GMT) #1, and Minimum Delay Data Format (MDDF) or Launch Trajectory Acquisition System (LTAS) data. The TC input is 10 pps timing data generated by an ASCII Time Code Generator. This timing data is a backup should the normal GMT source (the GPS receiver and communications lines) fail after launch. Prior to launch, this data is ignored. The GMT timing data is down linked from the GPS satellites and fed to the real-time system through the GPS receiver. Four sources of MDDF or LTAS data can be accepted by the IBM Master computers. The MDDF data is radar range, azimuth, and elevation data. Data from each radar is a separate MDDF source. LTAS data is generated by the TELPRO IBM computers at the telemetry site. This data consists of earth centered position data in x, y, and z and velocity data in $\dot{x}$, $\dot{y}$, and $\dot{z}$. Output of the IBM Master is onto the ethernet where it is picked up by the Iris display systems. Separate sources of data are fed to the #2 IBM Master computer in IIP System #2.

1.2.2.6.2 Mobile Radar Systems

Four C-band radars operating in the 5400 - 5900 MHz range are available to support off-site operations. Three are mobile RIR-778Cs located at WFF and listed in Table 1-6. The fourth is a transportable RIR-778C currently located at Poker Flat Research Range. The mobile systems have eight foot antenna's mounted on a flatbed trailer; whereas the transportable system has a 12 foot antenna mounted on a pedestal attached to a concrete pad. The pad for the 12 foot pedestal must be established at each new support location. The eight foot antennas on the mobile systems provide 38 dB gain and beacon track out to ~ 3,745 Kilometers (KM); while the 12 foot antenna on the transportable system provides beacon tracking range of 60,000KM. Figure 1-37 shows an example of a typical mobile radar system at WFF. These radars may be transported by land carrier or ferried by air, sea, or rail.

The radars provide continuous, accurate, spherical-coordinate information on targets being tracked. Each radar tracks in either the skin or beacon (transponder) mode providing trajectory data for real-time display/evaluation and recording.

Co-located on the radar's pedestal is a television camera and optics assembly (see Figure 1-37). This optical system can produce quality pictures under lighting conditions ranging from cloudy, moonless nights to bright, noontime sun. Because of the radar's co-located optical system, either optically-derived angle data or derived azimuth, elevation, and range data from the radar can be provided.

The radar console and display subsystem located in an equipment shelter contains all the controls and indicators required for radar operation and calibration. System calibration is accomplish in one of two ways, star calibration or electronic boresight calibration. Star calibration is the most accurate method. The electronic boresight is mounted on a tower at a fixed distance from the radar. It can be operated in skin or

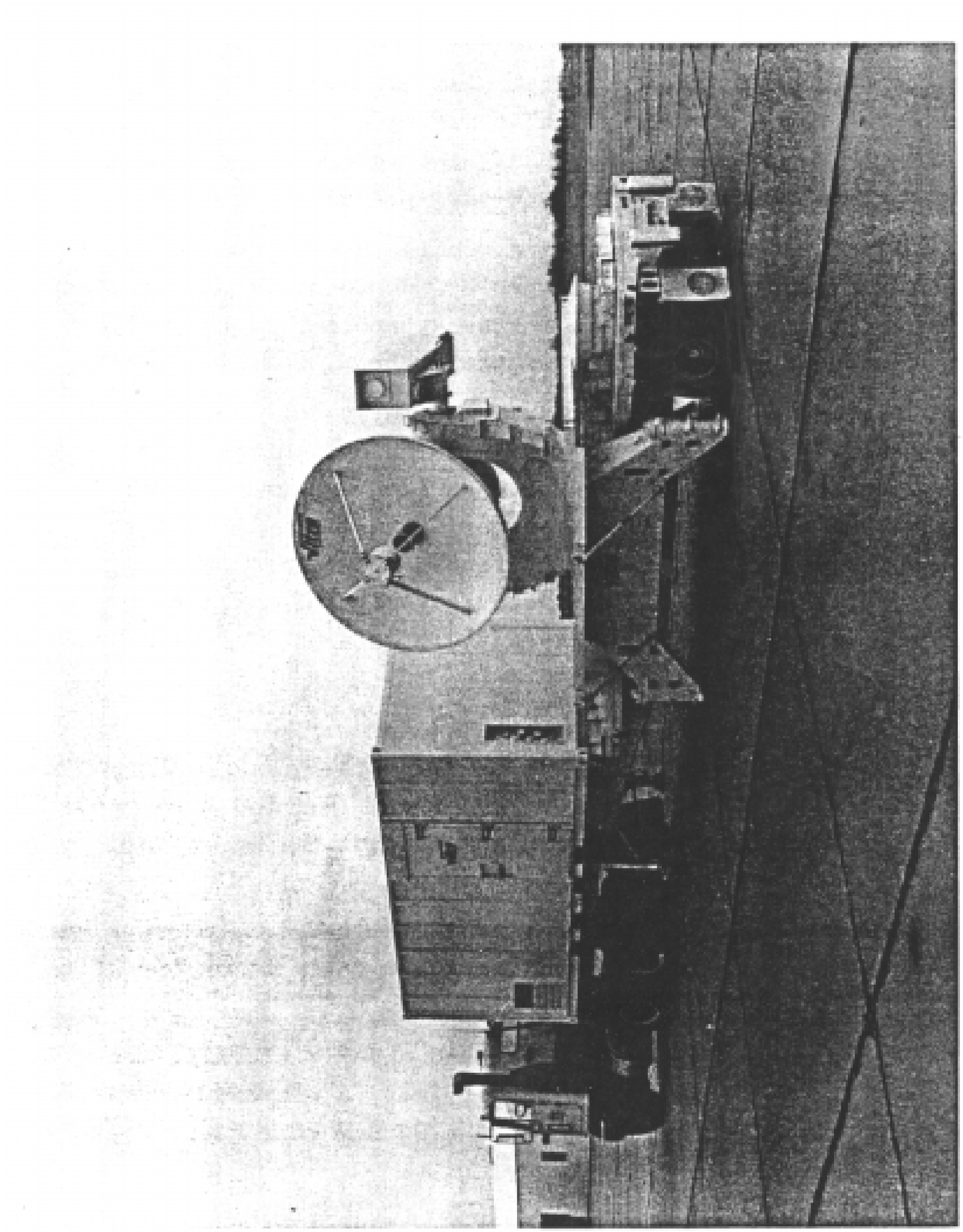


Figure 1 - 37: RIR-778C Radar System in the Travel Mode

beacon mode to calibrate the system and to provide an accurate standard to verify the radar's mission readiness.

1.2.2.6.3 Mobile Telemetry (TM) Systems

The mobile TM site performs the TM functions of data acquisition, tracking, recording, playback, and quick look data reporting (through real-time or playback). Like the range safety trailer the TM system is installed in a 48 foot C-130 container set up to accommodate user requirements.

There are numerous mobile telemetry system configurations that can be assembled to support alternate launch sites around the world. These configurations are made up of the components shown in Tables 1-6, 1-7, 1-8 and 1-11. Included are various antenna systems, pad mounted or stand alone, which can be assembled with four different vans. Antennas vary in size from ~6 to 26 ft (see Table 6). All systems support S-Band TM in the 2200-2400 MHz range. In addition, other assets support L Band (1650-1710 MHz), L Band (1435-1540 MHz), and P Band (215-260 MHz).

In general, WFF telemetry vans can be configured with various antenna configurations to satisfy mission requirements.

Telemetry systems are currently installed at PFRR. These systems could be moved to support operations from other locations. Because these antennas are pad-mounted, the new location would require the installation of a pad on which the antenna pedestal would be mounted.

Several systems are self-contained units with six foot parabolic antennas. They are compact, relatively easy to assemble, test, and certify. These systems are used to support the prelaunch portion of an operation. They have a broader beamwidth and are good systems to use for early acquisition.

TM data is processed in the telemetry van by the TELPRO computer systems. The TELPROs output video data which is fed to a video switch for display. TM data is digitally processed and graphically displayed locally in addition it is routed to the mobile MRCS for display in real-time.

Table 1 - 11: Miscellaneous Telemetry Systems

TRADAT V Telemetry System

Antenna Type	Frequency	Remarks
Tradat V Trajectory Data System. One single ten-turn helix antenna.	FM/FM	• The light-weight PCM ranging system provides trajectory data for vehicles such as sounding rockets or balloons launched at remote sites where radar sets are not normally available. • The antenna is normally attached to the telemetry antenna and interfaced with the host's autotrack controller system and transmits to an airborne PCM receiver/transmitter.

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1.2.2.6.4 Mobile Command Destruct System

The mobile command destruct system (MCDS) was upgraded to be a fully redundant mobile command system. It is used to uplink command signals to vehicles being launched from remote sites or as a backup in support of the Wallops Mainland system. Generally, these signals are for the purpose of command destruct; however, the MCDS system can also be used to uplink the command for payload deployment or other required vehicle functions. The system is remotely controlled by the RSO at WFF during flight. Data lines connect the system to the center for remote command functions, TM, and radar data. The MCDS is composed of two Henry Radio Company transmitters, a minimum of two antennas (either quad helix antenna with a 20 degree beamwidth and 18 dB gain, an omni with 360 degree coverage, or a single helix antenna with a 60 degree beamwidth and a 12 dB gain), and associated equipment. Each transmitter has an RF power output of ~1000 watts in the frequency range of 406.0 to 450.0 MHz. The transmitters are connected in a fail-over arrangement and mounted in a mobile van (See Figure 1-38). Transmitter modulation can be controlled locally. Frequency monitoring is also accomplished by personnel and equipment in the van to guard against radio frequency (RF) interference. See Table 1-12.

Figure 1 - 38: Exterior View of the MCDS 20 foot trailer

Table 1 - 12: Mobile Command/Destruct Systems

Transmitters | Antennas

Type	Frequency	Power	Type/Control	Gain	Control	Power	Features
(2) PST Power Systems Technology	406-450 Mhz	1000W	(2) Quad Helix Omni or Single Helix	18 db 15 db or 12db	PC Slaving System/ manual override	Build-in UPS	Fail-over transmitters. One hour set up at site if two compatible power sources available. Two antennas for redundancy.
(2) Henry Radio Company	406-450 Mhz	1000W	(2) Quad Helix Omni or Single Helix	18 db 12db	In 6M/20 ft shelter	Build-in UPS	Fail-over transmitters. One hour set up at site if two compatible power sources available. Two antennas for redundancy.

Notes: 1. Mobile systems can use several antenna combinations.
2. All helix antennas are left-hand circular polarization.

1.3 WFF COMMERCIAL VEHICLE SUPPORT CAPABILITY

Vehicles launched from Wallops Island are restricted to certain launch azimuths because of the populated land masses. The specific land masses affecting vehicle flight are: Assateague Island to the north, Cape Hatteras, the Bahamas, and South America to the south, and Bermuda, Europe, and Africa to the east (See Figures 1-9, 1-39 and 1-40). Specifically, risk criteria may not exceed a casualty expectancy of $Ec = 1X10^{-6}$. How close to the continental US or any populated land mass a vehicle may fly is affected by its flight profile and explosive characteristics due to destruct action, impact, or catastrophic events. This can vary significantly by types of vehicles and even among flights of the same vehicle depending on payload and other vehicle configuration differences. The destruct lines shown in Figure 1-40 are representative of those for the southerly launch of an orbital vehicle/payload. The destruct lines are constructed to protect the associated land mass, its public property, and civilian population. Flight azimuths to the north are generally limited, because of Assateague Island. The North Carolina Outer Banks (Cape Hatteras) limit the southern azimuths. In general, launch azimuths between 90° and 160° can be accommodated depending on impact ranges. Launches perpendicular to the shoreline are on an azimuth of 135°. For most orbital vehicles, the nominal limits translate into orbital inclinations of between approximately 38° and 60° (See Figure 1-9).

Trajectory options outside of these launch azimuths, including polar and sun-synchronous orbits, can be achieved by inflight azimuth maneuvers. Azimuths as low as 45° may be flown via a dogleg flight profile. This flight profile requires the vehicle to fly a launch azimuth of 78° or greater until the vehicle impact point is greater than 5 NM downrange. Azimuths greater than 130° may be approved by flight safety depending on stage impact points and casualty expectations associated with the impact and overflight areas. Each request is evaluated on a case-by-case basis.

WFF will protect Bermuda from a land impact no closer than 30 NM. Vehicles whose 3 sigma stage impact areas would infringe on the limit specified by this agreement are not allowed.

The overflight dwell time (the time that the IIP is over land) over South America or Africa is typically 6 - 10 seconds. The longer the dwell time, the longer the exposure, and the more risk there is to the population. Hazard analyses are conducted, as required, to determine the hazard, and modifications are made to the flight profile if dwell times exceed these figures. The limit on vehicle size at WFF is determined by the associated flight control hazard area, a radius of approximately 10,500 feet *is* used as a guideline, however, evacuation of non-government property may be acceptable to increase this hazard area if risk criteria is satisfied.

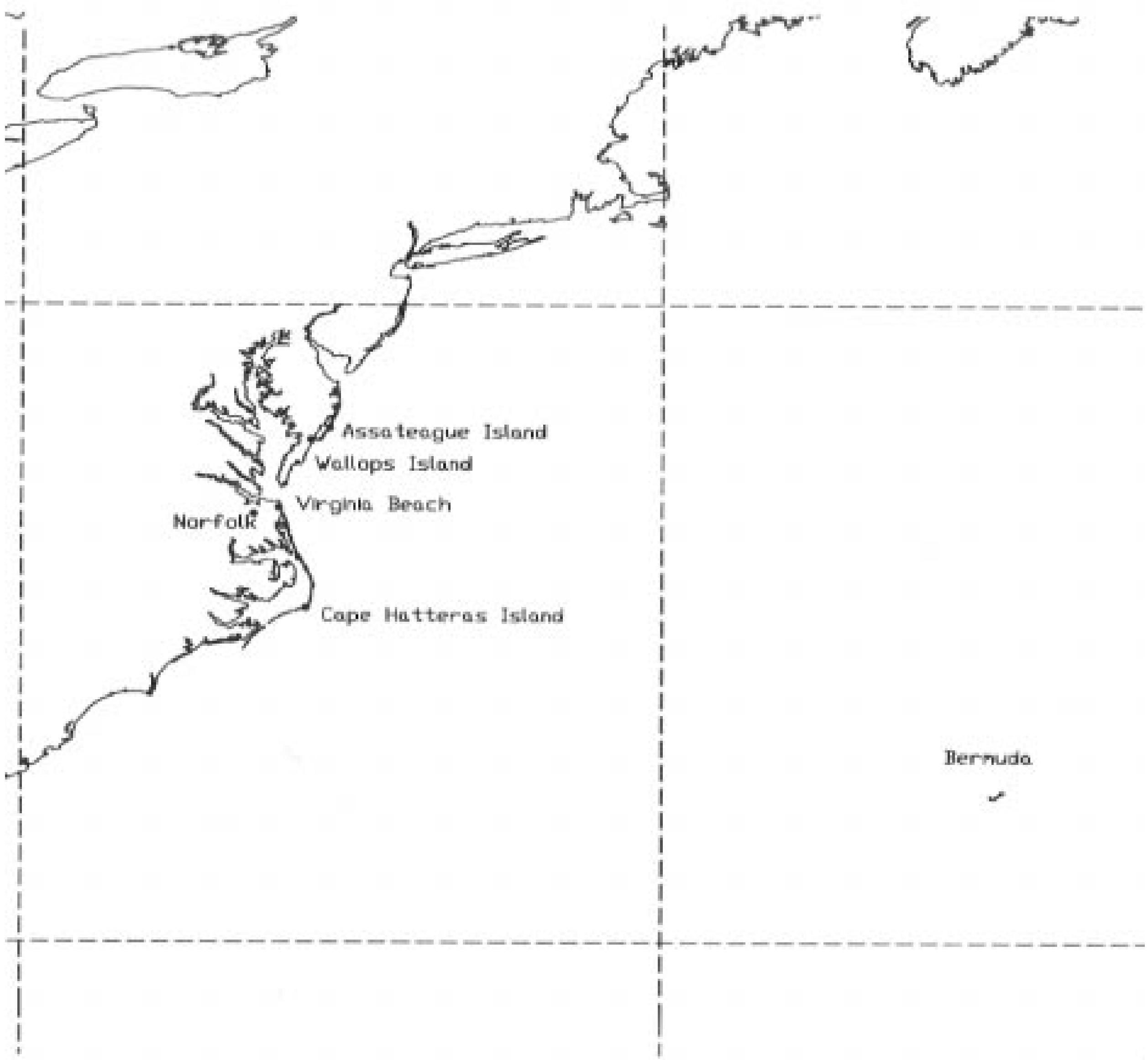

Figure 1 - 39: Wallops Flight Facility Coastal Limitations

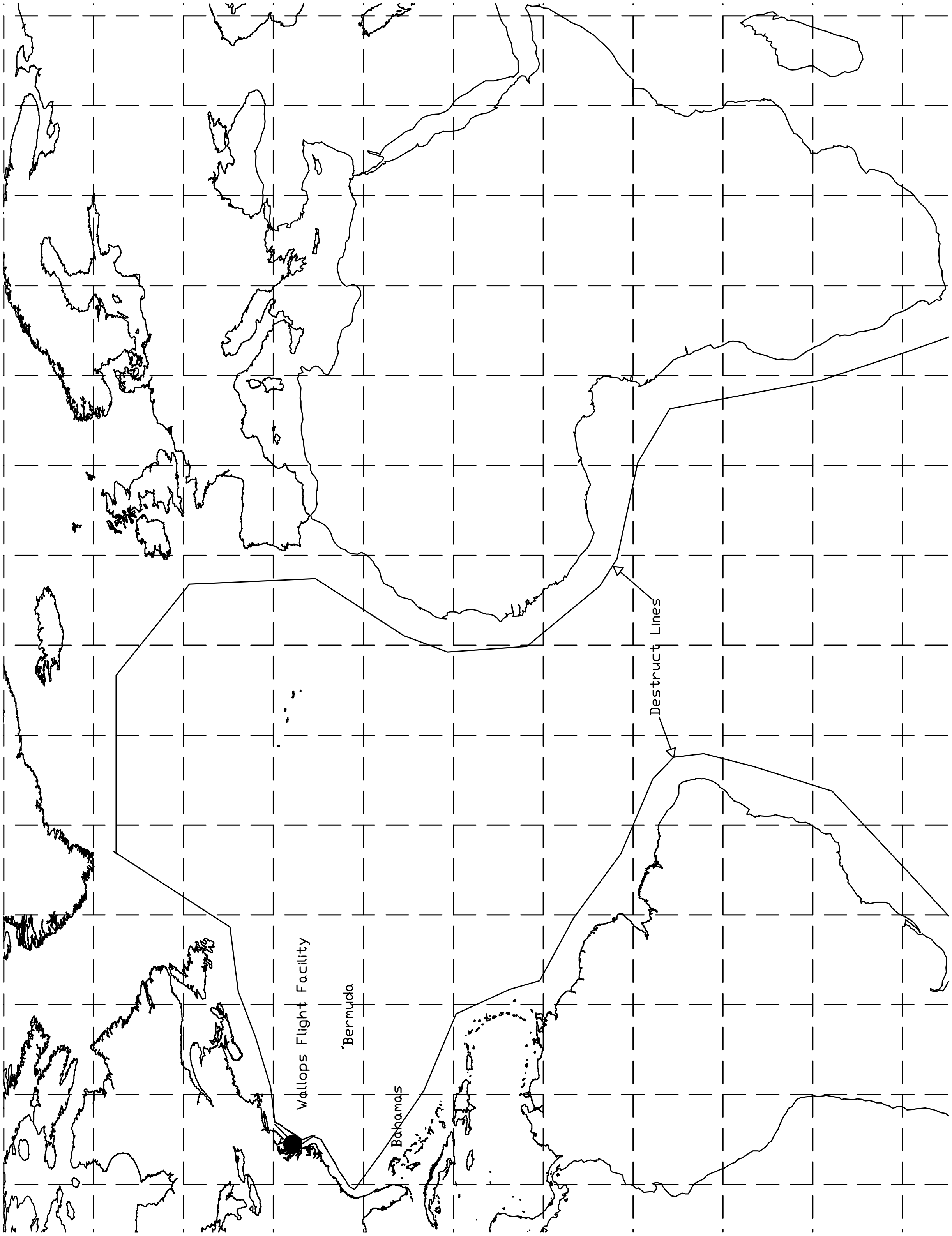

Figure 1 - 40: Wallops Flight Facility Overflight Areas & Destruct Limits

SECTION 2.0

WALLOPS FLIGHT FACILITY

RANGE SAFETY PROGRAM

2.1 INTRODUCTION

Section 2.0 describes the Wallops Flight Facility (WFF) Range Safety Program and provides an overview of the features that comprise this program. The Range Safety Program has authority and responsibility over both ground and flight activities such as test, checkout, assembly, servicing, and launch of launch vehicles and payloads to orbit insertion or earth impact. The following major topics are addressed:

2.2 Safety Organization and Responsibilities

2.3 Wallops Flight Facility Safety Policy

2.4 The WFF Range Safety Program

2.2 SAFETY ORGANIZATION AND RESPONSIBILITIES

The responsibility for safety at Wallops Flight Facility is vested in the Director, Goddard Space Flight Center (GSFC). The Suborbital Projects and Operations Directorate (SPOD) at the GSFC/WFF is charged with the responsibility for the overall management, operation and support of NASA's sounding rocket and balloon programs and the conduct of aeronautical research. This function is located at the Wallops Flight facility, Wallops Island, Virginia. A description of the safety related elements, confined to the office level, within this directorate and their respective responsibilities is provided in Section 1. Following is a more detailed discussion of responsibilities of the Safety Office and the Range and Mission Management Office who are involved in the ground and flight safety operations under the SPOD. These offices support the WFF Range Safety initiative, both directly and indirectly, and are responsible for the following activities:

- performing safety analyses and developing Ground Safety Plans, Flight Safety Plans, and Data Packages for all applicable programmatic missions including rocket, balloon, and aircraft.

- reviewing and approving User-generated safety plans.

- Implementing and developing flight safety and ground safety programs.

- approving all potentially hazardous operating procedures, providing insight into hazardous operations and determining those operations to supervise/oversee and implementing the Ground Safety Plan.

The responsibility for implementing WFF safety policy, criteria, and planning at ranges other than WFF is delegated according to the following hierarchy:

- The GSFC/WFF Flight Safety Officer (FS0)

  NOTE: The individual who mans the primary Safety Officer position is called the Flight Safety Officer (FSO) while the individual who mans the Senior position is called the Range Safety Officer (RSO).

- The RSO designee

- The GSFC/WFF Campaign Manager

- The GSFC/WFF Project Manager

2.2.1 The Safety Office

The Chief, Safety Office has collateral duties as the Program Safety Officer, allowing direct reporting to the Director, SPOD, on program safety issues (see Figure 2-1). In meeting its responsibilities for portions of the Range Safety Program, and for initiating the development of new methods, techniques, procedures, or systems to reduce hazards and improve operating techniques, this office performs the following activities:

- plans, develops, and provides functional management of Directorate policies and procedures for ground and flight safety, mission assurance, reliability and quality assurance.

- performs engineering analyses of ground and flight systems, environmental conditions, and operating activities to assure safety, reliability, and flight-worthiness.

- Plans, establishes, or approves operational safety precautions for protection of personnel, property, and the public from hazards generated by ground and flight systems or activities, including flight safety monitoring and control of launch vehicles, review of preflight and design data, and investigation of failures or accidents

- performs research and development of techniques, systems, equipment, devices, and procedures for both ground and flight activities to assure safety, reliability, and quality.

- conducts systems safety and reliability analyses to determine quantitative or qualitative evaluation of risks.

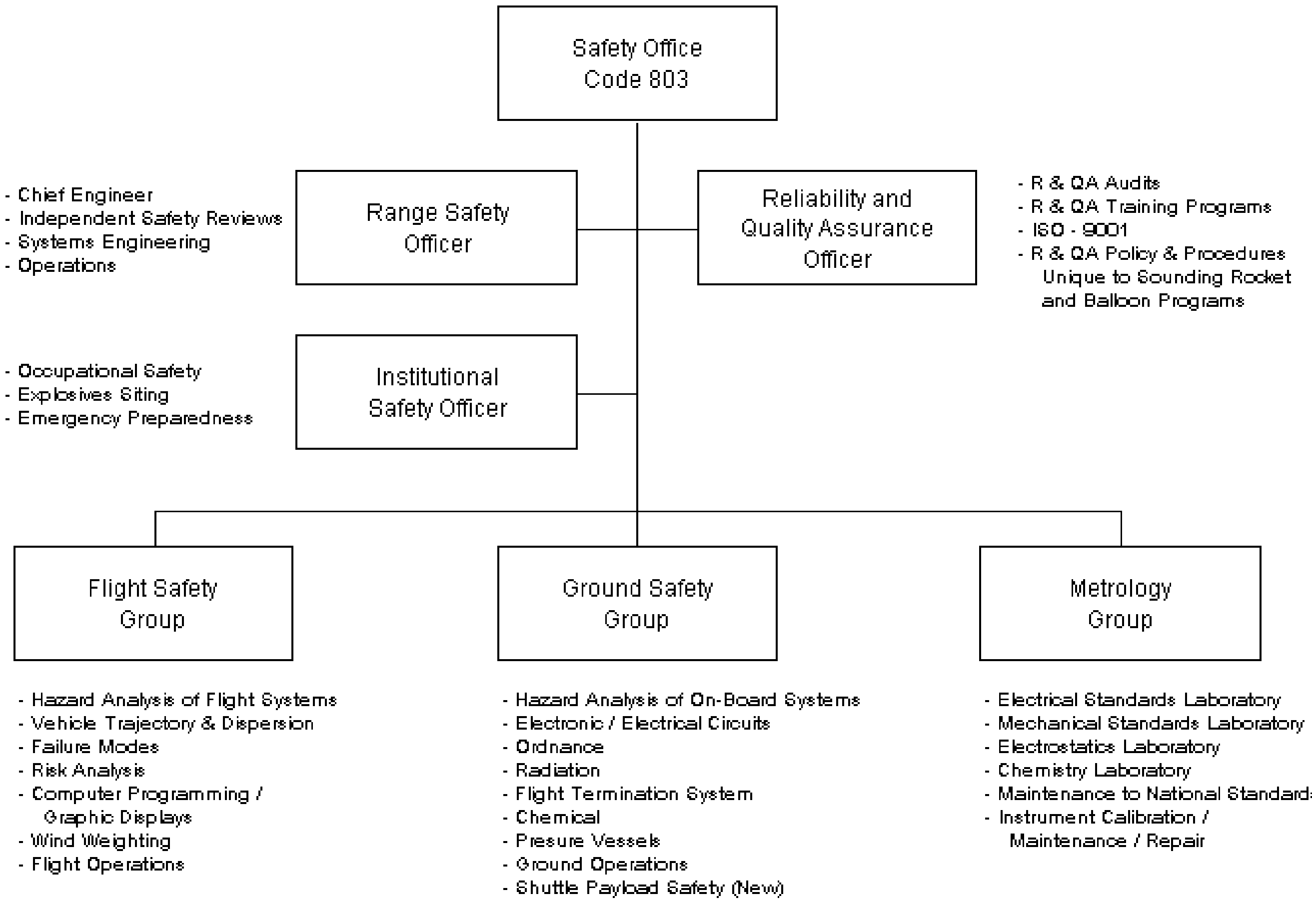

Figure 2 - 1 WFF Safety Office

- assembles, prepares, and publishes Safety Analysis Reports and/or vehicle Range Safety plans.

- plans and coordinates safety aspects of launch operations, including development of real-time computer programs and displays, range clearance and Range Safety limitations, assembly and pad procedures, and wind weighting performance records for each vehicle launched.

- provides the Operations Safety Supervisor (OSS).

- provides a Range Safety team to support each range activity.

- Implementation of the above activities is performed by organizational elements under the safety office, these consist of the following:

2.2.1.1 The Range Safety Officer

- Chief Engineer within the Safety Office

- independent safety reviews
- systems engineering and operations associated with range safety activities.

2.2.1.2 The Reliability and Quality Assurance Officer

- R&QA Audits
- R&QA training programs
- ISO-9000 standards
- R&QA Policy and Procedures unique to sounding rocket and balloon programs.

2.2.1.3 The Institutional Safety Officer

- Occupational safety
- Explosive siting of hazardous facilities
- Emergency preparedness.

2.2.1.4 The Flight Safety Group

- Hazard analysis of flight systems
- Vehicle trajectory and dispersion
- Vehicle failure modes
- Risk analysis
- Computer programming/graphic displays
- Wind weighting
- Flight operations

2.2.1.5 The Ground Safety Group

- Hazard analysis of on-board systems
- Electronic and electrical circuits
- Ordnance
- Radiation
- Flight termination system

- Chemical
- Pressure vessels
- Ground operations
- Shuttle payload safety

2.2.1.6 The Metrology Group

- Electrical standards laboratory
- Mechanical standards laboratory
- Electrostatics laboratory
- Chemistry laboratory
- Maintenance to national standards
- Instrument calibration/maintenance repair

2.2.2 The Range and Mission Management Office

The Range and Mission Management Office serves as the principle source of project management support for the Directorate's flight projects and operations. This office is responsible for the overall management of the Test Range and mobile campaigns, including scheduling of resources, and coordination with external agencies such as other government agencies, commercial entities, and international organizations. This office also provides technical operational and management assistance to other organizations at Wallops, for example the Safety Office. In addition, this office is responsible for implementing projects safely, successfully, within assigned schedules and budgets, and managing project support personnel.

2.3 WALLOPS FLIGHT FACILITY RANGE SAFETY POLICY

It is the NASA policy, implemented by WFF, to ensure that the risk to the public, to personnel at launch sites, and to national resources is minimized consistent with mission requirements. On occasion, approval of activities that exceed accepted risk criteria will be granted based on national need, mission requirements, or risk mitigation techniques. Risk to the general public and foreign countries from WFF operations will meet, but not exceed, the risk level of public exposure from launch operations established by Goddard Management Instruction (GMI) 1771.1. This is the governing document for Range Safety policies, criteria, and requirements for controlling and minimizing these risks. It is approved and signed by the GSFC Director and can be revised only with the concurrence of the Director.

Range Safety is the responsibility of the WFF and the range user, and WFF policy requires professionalism and sound judgment of its personnel to conduct commercial space activities in a manner that will aid in the reduction of risks inherent in performing launch vehicle, aircraft, balloon, and related operations. WFF safety personnel developed the Range Safety Manual that identifies the Range Safety requirements for implementing GMI 1771.1.

The WFF safety personnel become involved with any new program as early in the process as possible to aid in the reduction of costly engineering changes or scheduling delays later in the program flow. Commercial range user coordination with Range Safety is established through the Range Support Manager (RSM) of the Program and Mission Management Division.

2.4 THE WFF RANGE SAFETY PROGRAM

The objective of the Range Safety Program is to ensure that all range users being supported by WFF organizations conduct their operations within acceptable safety limits as established by WFF, consistent with mission requirements and national needs. The goal is to process and launch vehicles and payloads safely, efficiently, and economically. The range user assumes safety responsibilities by adhering to safety regulations and notifying WFF of any potential safety issues.

The Goddard Space Flight Center implements the requirements of the following laws and directives:

- National Aeronautics and Space Act of 1958, as amended
- Commercial Space Launch Act of 1984, as amended and recodified

- Goddard Management Instruction GMI 1300.2, Policies and Procedures for the Use of the Goddard Space Flight Center/Wallops Flight Facility Test Range

- Goddard Management Instruction GMI 1700.2B, Goddard Space Flight Center Health and Safety Program

- Goddard Management Instruction GMI 1771.1, Range Safety Policies and Criteria for Goddard Space Flight Center /Wallops Flight Facility

- Range Safety Manual (RSM-93) for Goddard Space Flight Center/Wallops Flight Facility

The WFF Range Safety Program implements portions of the above requirements consistent with their safety roles and responsibilities. The above list is not all inclusive but is provided as information to show typical laws and directives used in the safety process. The remaining parts of this section provide a detailed description of the requirements and methods used to implement WFF Range Safety policies.

2.4.1 Ground Safety

The WFF ground safety goal is to minimize the risks to personnel and property that result from operations conducted at WFF and other off-site locations and to prevent mishaps that could have detrimental consequences for NASA or the United States Government. In support of this goal, WFF has a policy that all hazardous systems be designed such that a minimum of two independent, unlikely failures or events (two-fault tolerant) must occur in order to expose personnel to a hazard.

In addition, an engineering review is made by the Ground Safety Officer (GSO) as the representative of the WFF Safety Office for all hazardous systems on the launch vehicle and all ground support equipment used to support hazardous systems or operations. The purpose of this review is to determine the nature and extent of the hazards and if the systems have adequate built-in safety features. If personnel must be present during system operations, such as the pressurization of fuel tanks, the range user must perform a fault tree analysis to ensure that the system is two-fault tolerant. The results of this analysis are included in the Ground Safety Plan, which is approved by the Programmatic Safety Officer (Chief, Safety Office).

The flight termination system (FTS) is considered as part of the overall flight safety system and must be examined from the standpoint of system safety as well as quality assurance. WFF publishes the design, test, and data requirements for the airborne portion of the FTS in the Range Safety Manual and reviews and approves all installation and checkout procedures. The system is required to be designed and tested for redundancy and reliability. (See 2.4.2.4.2). WFF reviews and approves all design and test data for the ground transmitters as well as the airborne portion of the system.

Detailed procedures for handling, assembly, and checkout for all other hazardous systems such as ordnance, mechanical, pressure, and chemical systems must also be reviewed and approved by WFF Safety Office prior to the beginning of operations. In addition, each operational procedure is reviewed and approved by the Safety Office who has oversight authority and determines the need to monitor hazardous operations. The criteria used to approve and disapprove hazardous systems and procedures are found in the WFF Range Safety Manual.

When a program has been approved for launch from WFF, a Ground Safety Plan is published in an Operations and Safety Directive for each particular launch vehicle. The Operations and Safety Directive contains all hazardous systems and operations, danger areas, and personnel restrictions. It also identifies the potential hazards and describes the system designs and methods used to control the hazards.

As noted above, the goal of ground safety is to minimize the risks to personnel and property that result from operations conducted at WFF and other off-site locations and to prevent mishaps that could have detrimental consequences for NASA or the United States Government. To this end, detailed requirements for the control of hazards, for the design of ground support equipment (GSE), and for ground operations security have been established.

2.4.1.1 Hazard Control

The methods used to protect personnel and property and to minimize the risk in conducting potentially hazardous operations are as follows:

- Implement safety design criteria.
- Identify all the known hazards associated with a program.
- Minimize exposure of personnel to potentially hazardous systems.
- Establish safe operating procedures.
- Plan for contingencies.

Included in these methods are specific personnel limits, detailed hazard categories and classifications, and clear definitions of pre-launch and launch danger areas.

2.4.1.2 Ground Support Equipment

The design of ground support equipment (GSE) used to make measurements on or provide control of potentially hazardous devices, systems, or circuits that may affect the safety of personnel or property must be calibrated and certified and may not be used beyond the certification period established by Range Safety personnel. The types of devices, systems, and circuits in this category include electrostatic discharge hazards, electrical storm criteria, radiation systems, chemical hazards, hazardous chemical systems hardware, and pressure systems.

2.4.1.3 Ground Operations Security, Operational Controls, and Procedures

Security is maintained by the use of badges and control of access to danger areas. Special badges are required of all personnel for admission to Wallops Island and the other restricted areas. Workshops, launch areas, and facilities are restricted and placarded to identify the presence of hazardous materials and operations and to warn against unauthorized entry. Admission to such restricted areas is limited to personnel displaying the proper badges. Danger Area Access is controlled by the Danger Area Warning System and Roadblocks.

For all launch operations at the WFF, the Test Director (TD), Range Support Manager (RSM), Range Safety Officer (RSO), Ground Safety Officer (GSO) and Operations Safety Supervisor (OSS) exercise control over all personnel associated with the operation. For off-range operations, Para. 2.2 describes the hierarchy for operational control.

All NASA personnel, NASA contractors, experimenters, range users, and tenants are responsible for the following:

- Adhering to the requirements established in GMI 1771.1 and the WFF Range Safety Manual.
- Adhering to directions issued by the Test Director, RSO, and/or the OSS.
- Reviewing vehicle and payload operations with the OSS.
- Obtaining permission from the OSS before conducting any operation in assembly, test, or launch areas.
- Identifying active personnel for each operation to the OSS to ensure maximum personnel limits are not exceeded.

Range users are responsible for submitting comprehensive handling, assembly, and/or checkout procedures for all potentially hazardous systems for review and subsequent approval via the Range Safety Plan. Operations are not conducted until these procedures have been approved by the Safety Office. In addition, the following requirements apply:

- Under no circumstances will a potentially hazardous operation begin without prior approval.
- No unrelated tasks will be conducted on potentially hazardous systems simultaneously within overlapping Danger Areas. It is the responsibility of all supervisory personnel to prepare work schedules to comply with this requirement.

- Range users must obtain permission from the OSS prior to making a power switch on any vehicle/payload or ground support system.

- Prior to conducting a launch operation, WFF generates emergency procedures and forms an emergency response team to be used in the event of a launch abort. Range users must identify personnel selected to participate on any emergency team.

2.4.2 Flight Safety

Flight Safety encompasses all prelaunch, launch, and postlaunch safety activities that pertain to the flight of a vehicle. The flight safety goal is to contain the flight of all launch vehicles and to preclude an impact that might endanger human life or cause damage to property, or have detrimental consequences for NASA or the United States Government. Although the risk of such an impact can never be completely eliminated, the flight must be carefully planned to minimize the risks involved while enhancing the probability of attaining mission objectives.

2.4.2.1 Flight Safety Policies

As defined in the GSFC GMI 1771.1 and the WFF Range Safety Manual, flight safety is concerned with the containment of vehicle flight within approved operational areas and the impact within planned impact areas of such flight components as spent stages, balloons, payloads/parachutes, and payload fairings.

WFF is responsible for flight safety until all flight components have impacted the earth or have achieved orbital insertion. To meet this responsibility, a flight safety program is implemented to protect the public and participating personnel from all hazardous launch activities and operations conducted at WFF and at mobile ranges operating at remote sites. For operations conducted at other established ranges, WFF is responsible for ensuring that NASA personnel, contractors, and experimenters are not exposed to risks greater than the acceptable risks established in GMI 1771.1.

Each mission has its own unique set of variables, including vehicle aerodynamics and ballistic capabilities; azimuth and elevation angles; wind, air, and sea traffic; and proposed impact areas. These variables require that a flight safety analysis be performed for each mission. Vehicle design, reliability, performance, and error predictions for each case are reviewed by Range Safety personnel to certify the flight-worthiness of all launch vehicles, missiles, drones, and other similar vehicles under their authority.

Flight safety data are prepared by the Safety Office prior to any launch operations where WFF has flight safety responsibilities. These data are published in a Flight Safety Plan, which becomes a part of an Operations Safety Directive (OSD), and describe the proposed vehicle flight and the means to contain it safely. Safety restrictions or requirements are also documented in the Flight Safety Plan for each operation.

Flight safety for aircraft operations ensures that operations are conducted within the limits established in the Operations Safety Directive and that public exposure to risk does not exceed the limits defined in GMI 1771.1.

2.4.2.2 Flight Safety Philosophy

Flight safety philosophy focuses on the launch vehicle itself and on the risks of launching the vehicle. The launch vehicle must meet safety standards and limitations to satisfy the WFF flight safety criteria published in the WFF Range Safety Manual. To satisfy these criteria, the range user must provide information about the vehicle and payload as early as 12 to 18 months, depending on vehicle complexity and the safety office personnel familiarity with the vehicle. A schedule describing the timeline for documentation from the user will be established on a case-by-case basis. Range Safety performs a safety analysis on this information and determines the required safety limitations. The RSO monitors the operation to ensure that all safety criteria are satisfied. Range personnel coordinate with range users, government agencies, and affected countries.

For flight safety purposes, risk is defined as the probability of a vehicle impacting in an undesirable location or the likelihood of a vehicle impact killing or injuring people. The role of Range Safety is to evaluate the inherent risk in an operation, ensure that the risk does not exceed acceptable criteria, and minimize the risk as much as possible. The flight safety criteria are based on exposing the public to risks no greater than those encountered on a daily basis. Since historical statistics show that the expected number of fatalities is approximately five in 10 million per 20 mile automobile trip and seven in 10 million per aircraft departure, the WFF casualty expectation of one in a million per launch results in the same order of magnitude of risk to the public as does everyday automobile and air travel.

Since the risk inherent in launch operations cannot be completely eliminated, flight safety criteria are expressed in probability terms. Populated areas are protected by establishing a maximum acceptable risk level for those areas. The Wallops flight safety criteria are similar to those used by other national ranges in that the numbers represent collective risks per category for the mission. Public risks and Participant risks are not combined. They are calculated separately for each criteria for each mission. Defined in GMI 1771.1 and the Range Safety Manual, these criteria are as follows:

- Casualty Expectation Criteria - Public risk: The number of casualties as a result of all mission activities must be less than, or equal to, 1.0×10^{-6}. Participant risk: This figure is 1.0×10^{-5} for personnel participating in the launch operation. This criteria contains risks to all overflight areas but does not include risks to personnel aboard ships and aircraft.

- Ship Impact Probability Criteria - Public risk: The probability of an object impacting a ship must be less than, or equal to, 1.0×10^{-5} for each impact area. Participant risk: Criteria are the same for ships participating in the launch operation.

- Aircraft Impact Probability Criteria - Public risk: The probability of an object impacting an aircraft must be less than, or equal to, 1.0×10^{-7} for each impact area. Participant risk: Criteria are the same for aircraft participating in the launch operation.

- The probability of an object impacting on lands for which impact permission has not been received is a factor in determining mission approval.

- Special case criteria may be established to provide safety for facilities and public areas whereby a safety analysis report documenting the mission risk level is prepared by Range Safety personnel and approved by the SPOD Director.

2.4.2.3 Flight Safety Restrictions

Safety restrictions are established by Range Safety personnel for vehicles launched from, or managed by, the WFF. In general, these restrictions state that the vehicles must be launched in a direction and on an azimuth that provides public protection of land masses and populated areas from debris. All flights must be planned in accordance with impact agreements and must be conducted so that the planned impact or reentry of any part of the launch vehicle over any land mass, sea, or airspace does not produce a casualty expectation greater than 1.0×10^{-6} for the mission. In addition, they must not produce an impact probability on private or public property that is unacceptable due to safety or political concerns unless a Safety Analysis Report is prepared and approved, or it can be proven that:

- The reentering vehicle will be completely consumed by aerodynamic heating, or

- The momentum of solid pieces of the reentering vehicles will be low enough to preclude injury or damage, or

- Formal government or private agreements allow the use of the land mass for impact or reentry.

No vehicle may overfly a populated area in violation of previous governmental or private agreements unless the following criteria are met:

- The vehicle is in orbit;

- The probability of an overflight failure does not violate acceptable WFF impact criteria; or

- The overflight is approved by the Director of the Suborbital Projects and Operations Directorate.

For unguided vehicles/sounding rockets that do not carry a flight termination system, wind weighting procedures as outlined in APPENDIX A must be accomplished to ensure that flight safety requirements concerning public safety are met.

2.4.2.4 Flight Termination Systems

Wallops Flight Facility policy requires an FTS on each stage of a launch vehicle that is capable of thrusting unless it is shown that the flight is inherently safe, a condition determined by probability estimates based on known system errors and the following set of qualifying conditions:

- The launch vehicle does not contain a control or guidance system and is incapable of assuming any trim angle that produces sufficient lift for the vehicle to violate the planned impact area.

- The launch vehicle control system does not have sufficient turning capability to violate the planned impact area.

- For new or modified sounding rockets, the proposed launch elevation angle does not exceed 80^0, and the proposed azimuth is such that the geographical advantages of impact areas are recognized. If the vehicle reliability has been established, the 80^0 launch elevation angle limit may be increased to 85^0 provided the probability of failure does not violate flight safety limits and the impact criteria are not violated.

If a launch vehicle cannot meet the above set of conditions, a FTS must be used whereby thrust may be terminated, stage ignition prevented or delayed, or other means employed to ensure that the impact and overflight criteria are not exceeded.

2.4.2.4.1 Flight Termination System Design Criteria. Range Safety personnel determine the need for an FTS for each vehicle. The type of vehicle being launched, vehicle performance parameters, and safety related hazards and risks are evaluated by Range Safety personnel who require an FTS if it is needed to satisfy WFF safety criteria. Once the need for an FTS has been determined, the Range Safety Manual requires that the FTS meets the design features specified in the Range Commanders' Council Document, "Flight Termination Systems Commonality Standard," Standard 319-92. The Commonality Standard provides design, test, and data submittal requirements for FTSs to be used with unmanned flight vehicles intended to be flown at more than one range. The design, test, and quality assurance standards for FTSs closely follow those stated in numerous regulatory documents, such as:

- Goddard Management Instructions

- Goddard Handbooks

- American National Standards Institute Publications (ANSI)

- Code of Federal Regulations
- NASA Safety Standards
- Department of Defense Standards
- Military Specifications and Standards
- GSFC/WFF Publications

These specifications are acceptable for use on specific flight vehicles at any Major Range and Test Facility Base (MRTFB), including NASA launch facilities. The FTS design must be approved by Range Safety before launch approval can be granted. After FTS design approval, no modifications may be made without prior approval by Range Safety. Modification without safety approval may result in the revocation of the approved status of the system. The range user must maintain appropriate configuration management documentation, revising it to reflect approved modifications to the FTS. Copies of this information are made available to Range Safety. The major components of an FTS are the antennas, receiver-decoders, ordnance, power supplies, wiring harnesses, and telemetry. A diagram of a generic FTS is shown in Figure 2-2.

2.4.2.4.2 Flight Termination System Reliability Goal. The overall system reliability goal of the FTS is a minimum of 0.999 at the 95 percent confidence level. This reliability goal is satisfied by using the design approach and testing requirements described in Standard 319-92 and RSM-93. Guidance for establishing or implementing a reliability program is found in MIL-STD-785A, “Reliability Program for System and Equipment, Development and Production”.

System reliability must be verified by test or analysis in accordance with the Part Stress Analysis of Military Handbook 217, “Reliability Prediction of Electronic Equipment”, or equivalent, using the worst-case missile launch environment. Mission time used in calculations include pre-flight checkout time plus a minimum of 30 minutes for hang-fire waiting periods plus 150 percent of the predicted maximum time of hazardous flight. Not later than six months prior to FTS component or system testing, the user is required to submit the Reliability Requirement Analysis and Reliability Test Plan to the range for review and approval.

Further, the FTS must be redundant and be designed to eliminate the possibility of a single-point failure inhibiting the function of the system or causing an undesired output of the system. A single-point failure analysis is required to be performed to verify compliance with this requirement.

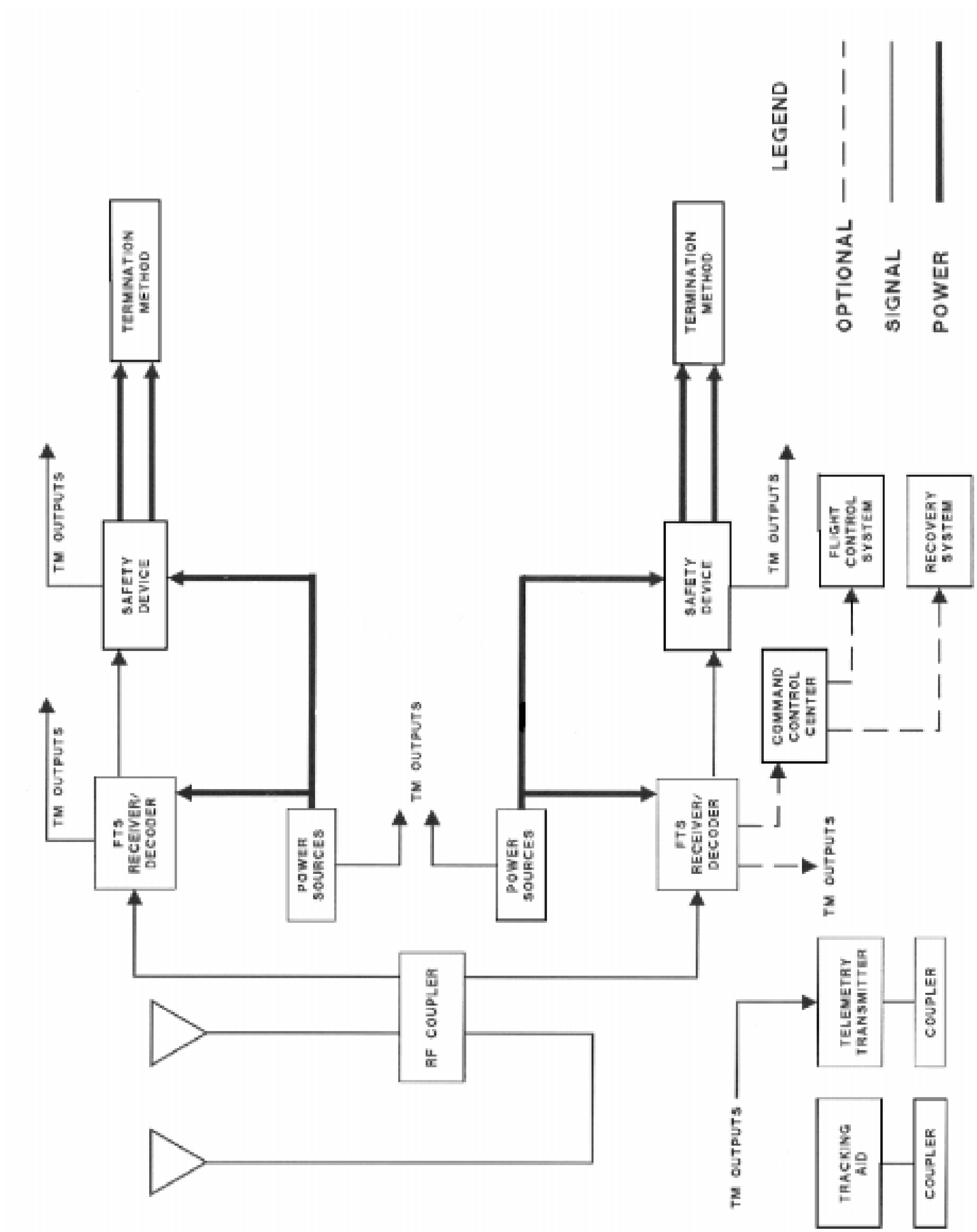

Figure 2 - 2 Typical ELV Flight Termination System

Prior to launch, laboratory checks are performed on the FTS receivers to verify the minimum command receiver specifications as defined in RSM-93. In addition, functional tests are performed to verify the complete system from antennas to destruct simulators that are used in place of the destruct ordnance during system testing.

2.4.2.5 Flight Safety Analysis

Approximately six months to one year before launch, WFF performs a preliminary flight trajectory analysis to determine if populated land areas can be protected for the normal planned trajectory of the launch vehicle plus various failure modes the vehicle may encounter. The nominal trajectory is examined to determine where the various non-orbital stages would impact and where the ground track of the vehicle would cross, or overfly, land. First, the impact points are examined, in association with dispersion inaccuracies in the guidance system or vehicle propulsion systems, to determine how far off the coast the impact point must be to meet the casualty expectation criteria. Next, overflight risks are determined by considering the dwell time over land where the Instantaneous Impact Point (IIP) crosses and the population densities near the ground track.

WFF protects land areas and surface traffic, such as aircraft and ships, by establishing limits to prevent the launch vehicle from reaching certain undesirable areas, given the reliability of the destruct system. In addition, WFF conducts surveillance operations in areas where there is a reasonable chance of shipping concentration being a problem. If the probability of some vehicle failure mode occurring can be expressed reliably in quantitative terms, a calculation can be made as to how far an event must be from a populated land area to reduce the risk to an acceptable level, and the trajectory can be adjusted accordingly. There are no written criteria for how far from land an impact must be; however, there are WFF guidelines that indicate it should be at least 100 nm off the coast for foreign countries. To ensure no land impact, a buffer distance is calculated, considering system error, FSO reaction time, and three-sigma dispersion of the vehicle ground track. Destruct lines are set so that if the FSO destroys the vehicle at the time the vehicle crosses the line, debris will impact short of the land mass. When analyses of the debris pattern are made, the velocity imparted to the pieces by an exploding vehicle is considered as well as the accuracy of the display system.

For all commercial missions conducted from WFF, as well as other missions for which WFF has safety responsibilities, a flight safety analysis is performed by Safety Office personnel. The information received from the range user, listed in Table 2-1, is used as the basis for the analysis.

TIME	EVENT	PURPOSE	POC	INPUT	OUTPUT
	START				
Issuance of MAD* & AMIS**	Project Initiation Conference (PIC)	Define Mission Objectives	*WFF Range Support Manager (RSM) *Program MIM*** *P/L Manager *Launch Vehicle MIM	Description of Payload & Proposed Orbit *Project team presents	*Formal memo from WFF & Program MIM documenting Manager PIC
Prior to P/L PDR	Safety TIMs	Address Specific Safety Issues	*WFF RSM *P/L Manager *Launch Vehicle MIM	*Formal presentation of issue(s) by Project team & WFF Range Safety	*Memo from P/L or Vehicle MIM documenting status/ resolution
NLT L-18 months NLT L-9 months for sounding rockets	P/L PDR	Define system Preliminary Hazard Analysis (PHA)		*Project Team provides: -Preliminary Safety Analysis -Gross Analysis Hazard -P/L Design Documents & Drawings -Special Ops -Preliminary trajectory definition	
PDR plus 60 days PDR plus 30 days for sounding rockets	Preliminary Safety Data Package (SDP)	User provides Preliminary Safety Document for Vehicle, P/L, and Special Ops	*WFF RSM *P/L Manager *Vehicle MIM	*Project provides: -Preliminary Safety Data for Safety Plan development	SDP for review

* Mission Authorization Document
** Advanced Mission Integration & Support Document
*** Mission Integration Manager

Table 2 - 1: Typical ELV Data Requirements

TIME	EVENT	PURPOSE	POC	INPUT	OUTPUT
PDR plus 60 days PDR plus 30 days for sounding rockets	Safety TIMs	Discuss SDP	*WFF RSM * P/L Manager *Launch Vehicle MIM	*Project team presents: -Traj. Data -Safety Analysis -Facility mods -Preliminary OPS Plans	Formal memo from P/L or Vehicle MIM documenting status/ resolutions
NLT L-12 months NLT L-6 months for sounding rockets	P/L CDR	Finalize Design	*WFF RSM *P/L Manager *Launch Vehicle MIM *System Experts (P/L & Vehicle)	*Project Team presents: - Final P/L Design	*Preliminary Safety Approval (subsystem) *Final GHA
	Safety TIMs	Resolve A/Is* and Safety Issues	*WFF RSM *P/L Manager *Launch Vehicle MIM	*Project team Identifies: - Design changes - Operational methods - Testing	formal WFF/ Program MIM memo documenting resolution of issues
CDR plus 60 days CDR plus 30 days for sounding rockets	Operational Support System TIMs	Define Operational Support	*WFF RSM *P/L Manager *Launch Vehicle MIM	*Project team presents: -Mission Operation (data) requirements * WFF Safety presents: -Real Time Data Requirements	* RF Link Analysis *Mission Support Allocation

Table 2-1 (continued): Typical ELV Data Requirements

TIME	EVENT	PURPOSE	POC	INPUT	OUTPUT
L-75 Days	Final SDP	User provides Final Safety Document for Vehicle, P/L and Special Ops	* WFF RSM * P/L Manager *Launch Vehicle MIM	* Project provides: - Final Safety Data (official) for safety plan development	Approved SDP
L-75 Days	Final Hazard Procedures Submittal	User submits to Range the final procedures for all hazardous procedures	* WFF RSM * P/L Manager * Vehicle MIM	* Project team provides: - Procedures for hazardous operations	Proposed Hazardous Operations Procedures document
L-75 Days	System Safety A/I Resolution Meeting	Attempt to close out safety A/Is	*WFF RSM *P/L Manager *Launch Vehicle MIM	Project team and WFF safety resolve all action items	Formal WFF/ Program MIM memo documenting results
L-75 Days	Environment all Test Results	Collect Results for vehicle P/L, & A/C	* WFF RSM * P/L Manager * Launch Vehicle MIM	Project environmental team provides data	Test Result Reports
NLT L-60 Days	Final Trajectory Tape to WFF	Project delivers final trajectory tape to WFF	* WFF RSM * P./L Manager	* Project provides: -Trajectory data tape & -Inputs to WFF	Final Trajectory Tape (Required) Plan for Flight Approval)
L-60 Days	Final Flight Plan Submittal	Project delivers final Flight Plan for Aircraft Operations	* WFF RSM * P/L Manager	* Project provides: - Final A/C Ops Plan	Final Flight Plan
L-45 Days	Operational Procedures Approval	Internal WFF approval of Operational Procedures	WFF CC: Vehicle Project, P/L	WFF provides letter approving hazardous op. procedures	Formal statement from WFF identifying approved procedures

Table 2-1 (continued): Typical ELV Data Requirements

TIME	EVENT	PURPOSE	POC	INPUT	OUTPUT
L-30 Days	Mission Safety Review	Closure of all Safety A/Is	* WFF RSM * WFF Safety * P/L Manager * P/L	Final closure of A/I by Project team and WFF	Formal memo documenting Mission Safety Readiness
L-21 Days	OSD	Define Operational Safety Plan	WFF cc: all applicable organizations	* WFF provides: - Ground Safety Plan - Flight Safety Plan - Go/No-Go items OSD defines: - Requirements - Test Directives - Air Ops Plans	Final OSD
L-21 Days	FTS Certification	Test Plan & Documentation for FTS System	* WFF * Vehicle MIM	WFF defines FTS certification documents	FTS test plan and document
L-14 Days	Mission Readiness Review	To determine the readiness range, vehicle, payload & supporting site	* WFF RSM	Readiness Status	Readiness Status
L-5 Days	Flight Readiness Review	To determine the readiness of the L1011 & support aircraft	* WFF RSM	Readiness Status	Readiness Status
L-2 Days	Launch Readiness Review	To review all prelaunch testing & certification	* WFF RSM	Results of pre-launch testing & certification	Launch readiness certification
	LAUNCH				

Table 2-1 (continued): Typical ELV Data Requirements

2.4.2.5.1 Dispersion. The WFF Flight Safety Analyst performs calculations based on data received from the range user to determine dispersion characteristics of the launch vehicle to be flown. Dispersion of the impact location of a launch vehicle is the statistical deviation of the actual impact point from the nominal impact point due to uncertainties in modeling parameters; e.g., wind. It is used to calculate the probability of impacting within a given distance of the nominal impact point. This distance is commonly expressed as a sigma value (the square root of the average of the squares of the deviations from the mean) and is shown in Figure 2-3. For the non-nominal case WFF uses the probability of mission failure for overflight E_c calculations. The result of this calculation is compared to the maximum acceptable E_c to determine mission acceptability.

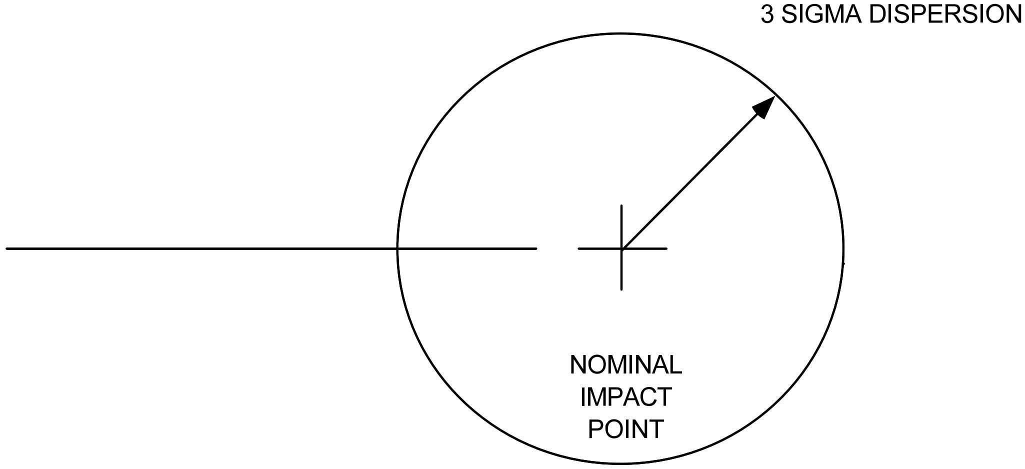

Figure 2 - 3 Dispersion

2.4.2.5.2 Land, Island, and Ship Impact Probability. The WFF Flight Safety Analyst calculates the impact probability associated with a specific launch vehicle. The probability of impacting an object such as a ship, aircraft, or a city/town is a function of three factors:

- Size of the object
- Distance from the nominal impact point
- Dispersion of the rocket

Figure 2-4 shows a graphical representation of the probability of impacting an object.

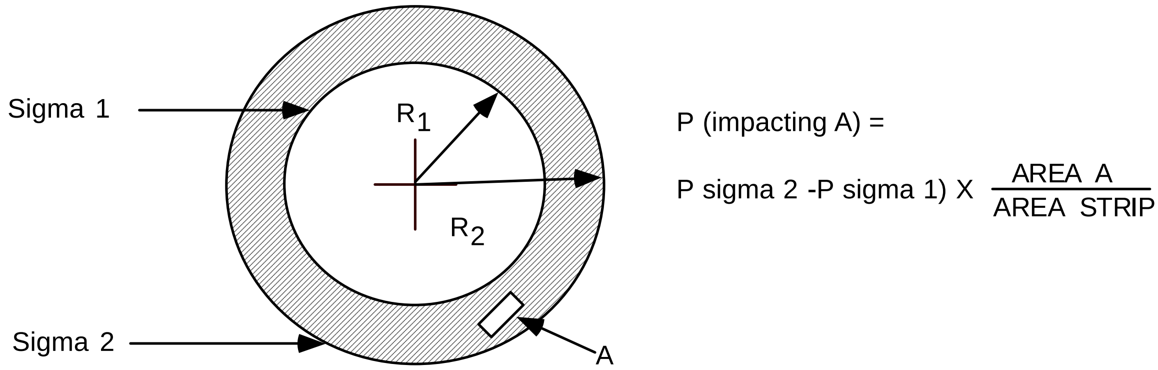

Figure 2 - 4 Probability of Impacting an Object

2.4.2.5.3 Casualty Expectation. The equation used for calculating casualty expectation (C_E) is:

$$C_E = P_i \times P_d \times A_l$$

where:

P_i = probability of impact

P_d = population density

A_l = lethal area

The population density is obtained from the latest published population data such as the US census data. A typical population density for the Virginia-Maryland coastal area is approximately 60 people per square mile. The lethal area of an inert piece of debris is the actual size plus a one foot buffer to account for the average size of a human being. If the impacting object has explosive capability, then this explosive effect must also be considered when calculating a lethal area. (See Figure 2-5.)

As stated in the WFF Range Safety Manual, the flight safety criteria to protect ships and aircraft are expressed only in terms of the probability of impact; therefore, C_E for ships and aircraft are not normally performed. The ship impact probability criteria is an order of magnitude higher than the C_E criteria. Since most ships operating in the WFF surveillance area are much smaller than an aircraft carrier, the real ship impact probability is less than the conservative estimate of 1.0×10^{-5}. For larger ships, it is possible to hit a ship and not produce any casualties.

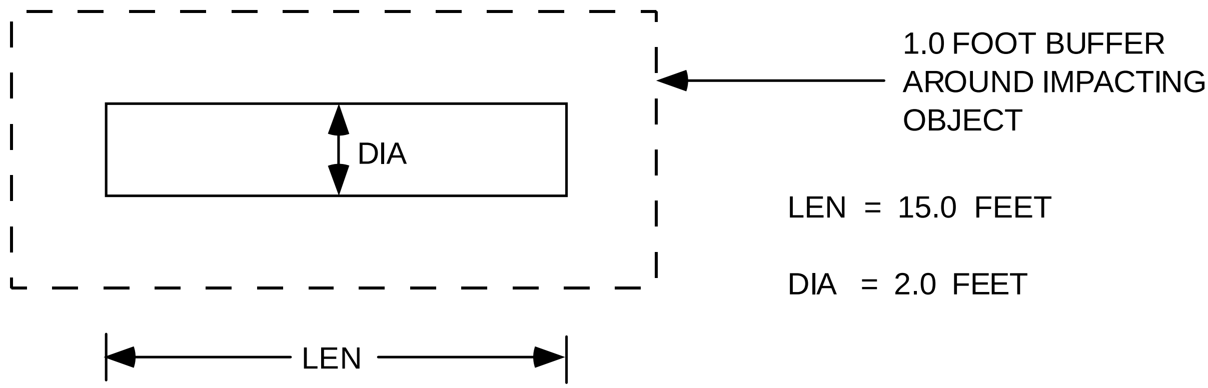

Figure 2 - 5 Lethal Area

The aircraft impact probability criteria is an order of magnitude lower than the ship hit criteria. The real aircraft impact probability is less than $1.0X10^{-7}$. However, embedded in the criteria is the assumption that an aircraft impact will cause the aircraft to crash with multiple fatalities.

2.4.2.5.4 Instantaneous Impact Point. The IIP is the point at which a launch vehicle would impact if it stopped thrusting at a given time, assuming a ballistic trajectory to impact. The IIP prediction capability can be used as a real-time tool by the FSO. At any time during the flight, where the impact would occur if the vehicle flight were terminated at that time can be determined. If the IIP track is heading toward a land area, the FSO can send the destruct command when the IIP track crosses the destruct line and significant pieces of the destroyed launch vehicle will impact short of the ILL (Figure 2-6).

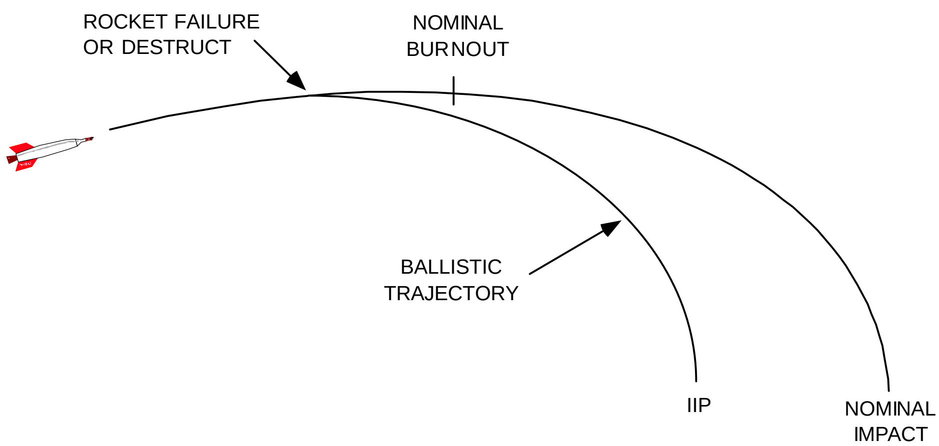

Figure 2 - 6 Instantaneous Impact Point

The IIP track can also be used to compute dwell time over a land area during overflight (Figure 2-7).

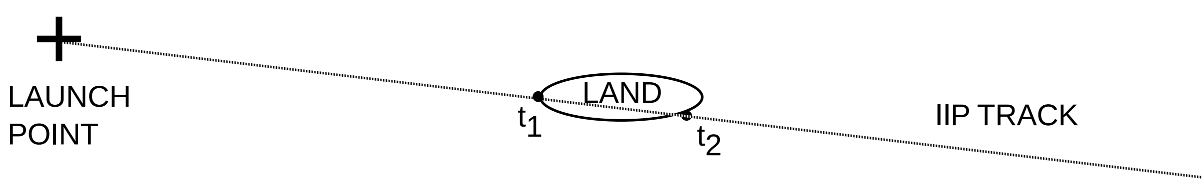

Figure 2 - 7 IIP Track for Computing Dwell Time

2.4.2.5.5 Mission Risk. Mission planners strive to ensure that all vehicle systems will work properly and that there will be no failures. However, Range Safety personnel must consider the likelihood and the effect of a vehicle failure. The various types of failure modes must be identified, their probability of occurrence assessed, and the resulting risk calculated. Vehicle dispersion is calculated from known system errors and does not normally consider vehicle failures. The impact area and resulting risk for each type of failure must be calculated separately. Thus, the total mission risk can be defined as follows:

$$CE_T = CE_{NF} \times P_{NF} + \sum_{i=1}^{n} CE_{F_i} \times P_{F_i}$$

where:

CE_T = total casualty expectancy

CE_{NF} = casualty expectation if no failures occur

CE_{F_i} = casualty expectation if a failure occurs

P_{NF} = probability of no failure occurring

P_{F_i} = probability of a failure occurring

The typical failure rate for rockets is two percent for mature rockets to five percent for new rockets. The most probable failure for an unguided rocket is no stage ignition. Another failure is to have significantly less than normal impulse such as a motor burn-through. Normally, such failures do not present a major safety problem at oceanic ranges such as WFF, but could be a problem at an interior range such as Poker Flat Research Range, Alaska. Guided rockets have additional failure modes. The guidance system could grossly malfunction causing the vehicle to deviate greatly from the planned flight path. Another failure mode is total guidance system failure. For these reasons, an FTS is required for guided vehicles.

2.4.2.5.6 Probability of Land Impact During Overflight. The probability of land impact during overflight, as shown in Figure 2-8, can be calculated using the following equation:

$$P_i = (P_f)(d\ T)/T$$

where:

P_f = probability of failure

d T = overflight time

T = total burn time

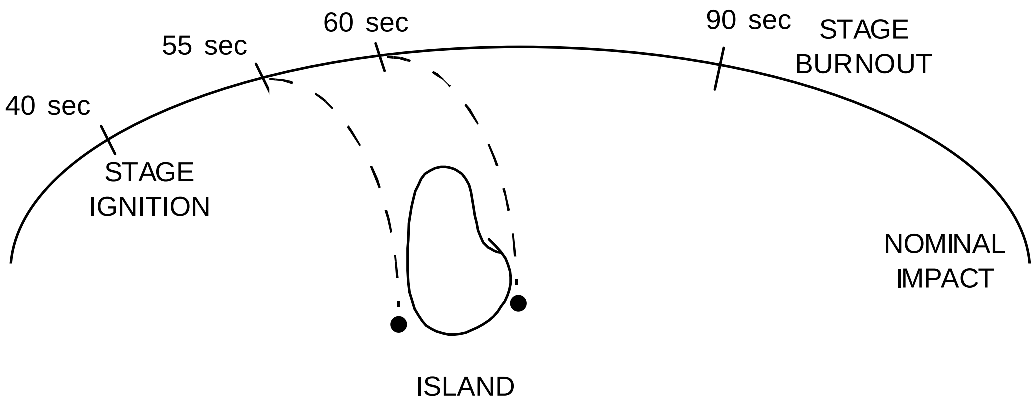

Figure 2 - 8 Probability of Land Impact During Overflight

2.4.2.5.7 Coriolis. Coriolis is the displacement of the vehicle impact point due to the earth's rotation during vehicle flight. In the Northern hemisphere, the effect of Coriolis is shown in Figure 2-9.

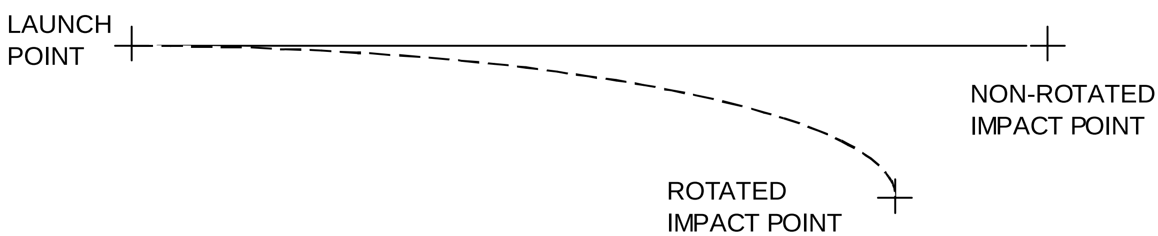

Figure 2 - 9 Coriolis Effect

For vehicles without an FTS, the flight safety analysis and limits are based on the predicted impact point. For vehicles with a FTS, the Coriolis effect must be included in the safety limit calculation (Figure 2-10).

CORIOLIS = AZIMUTH IMPACT - AZIMUTH BURNOUT

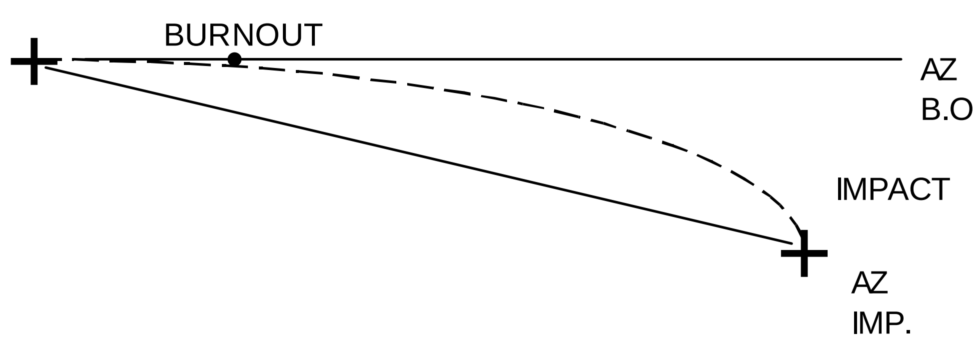

Figure 2 - 10 Azimuth Impact/Azimuth Burnout

2.4.2.5.8 Flight Safety Limits. A flight safety limit is a constraint on a launch parameter or a flight parameter. The purpose of a flight safety limit is to protect land areas and population from vehicle impacts. These limits are calculated differently depending upon whether or not a vehicle has an FTS.

Vehicles Without an FTS. Vehicles without an FTS cannot be controlled after they are launched. As shown in Figure 2-11, the impact point is a function of the effective launch parameters and vehicle dispersion. The risk level is based on impact probability and casualty expectation calculations. In general, launch parameters can be selected that satisfy the flight safety criteria. For example, the azimuth can be rotated away from the land area. At some point, an azimuth will be reached where the land impact probability and casualty expectation will satisfy the flight safety criteria stated in the WFF RSM.

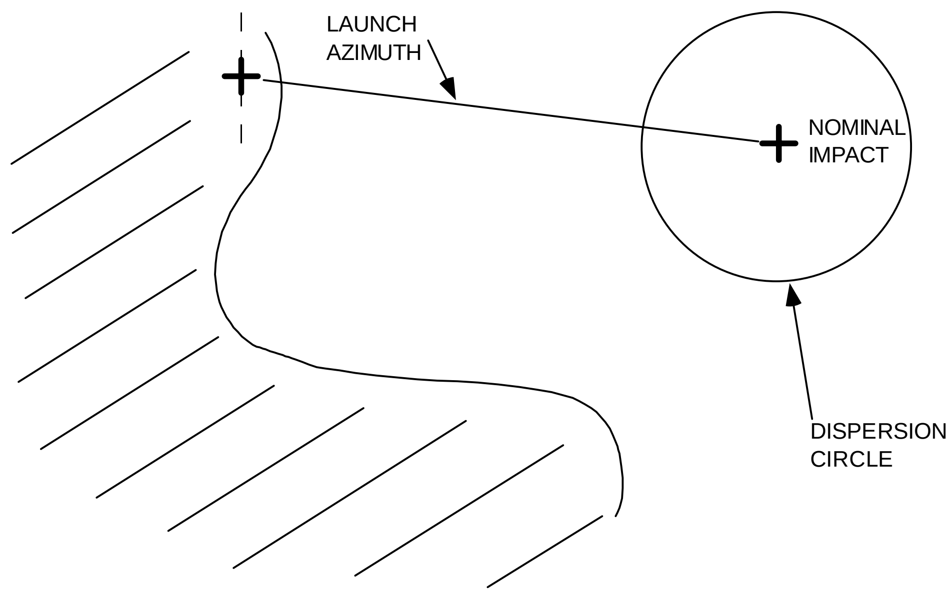

Figure 2 - 11 Impact Point for Vehicles Without FTS

Vehicles With an FTS. The flight of vehicles with an FTS can be terminated if they present a hazard to a land area. The flight must be terminated at such time that ensures that all pieces of the vehicle impact short of the land area. As shown in Figures 2-12 and 2-13, the limit is the closest point to land at which the flight termination command can be sent to ensure a safe impact.

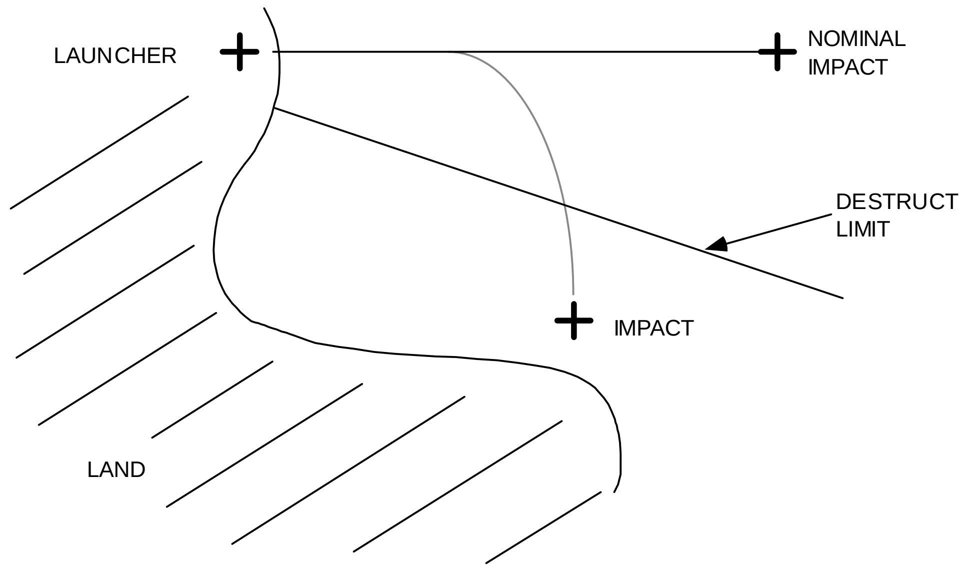

Figure 2 - 12 Impact Point for Vehicles With FTS

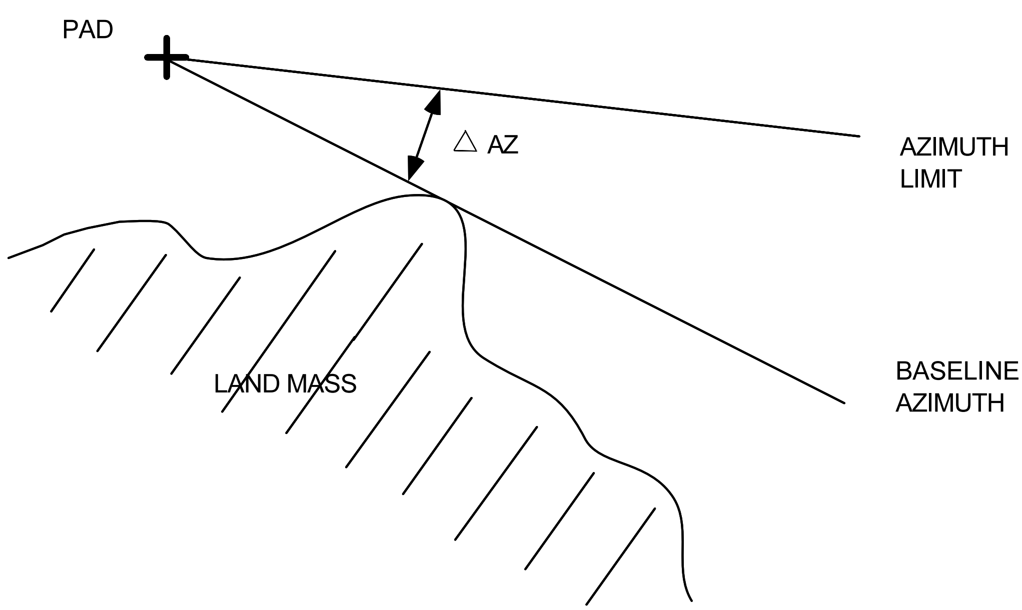

Figure 2 - 13 Flight Safety Azimuth Limit

The flight safety azimuth limit is delta AZ degrees off the baseline azimuth (from the launch pad to the point of land closest to the flight azimuth). Delta AZ is the sum of the following components:

- Data Source Inaccuracy - There is always some inaccuracy in the known position of the vehicle due to the inherent inaccuracies of the tracking and data display systems (0.5^0 is normally used at WFF).

- Coriolis - Due to Coriolis effect, the impact azimuth will be different from the flight azimuth at rocket burnout. Delta AZ due to Coriolis effect normally runs from 1^0 to about 5^0.

- Turning Rates - A guidance system gives the rocket the capability of turning (yaw or pitch) so many degrees before the FSO can ascertain the failure and send the destruct command (Figure 2-14).

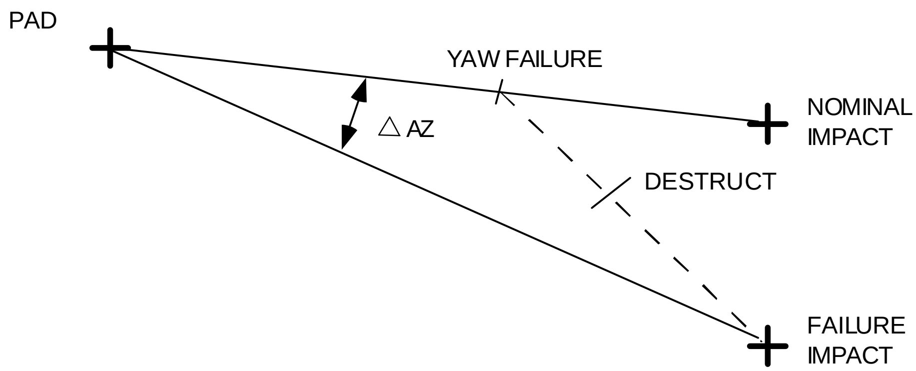

Figure 2 - 14 Turning Rates

The following assumptions are made:

- Maximum yawing (or pitching) capability

- Five second FSO reaction time (FSO reaction time may be 3 seconds if the IIP display is available)

- Maximum debris range

- As shown in Figure 2-15, land masses are normally protected by an additional buffer. The amount of this buffer varies from vehicle to vehicle, primarily as a function of impact range.

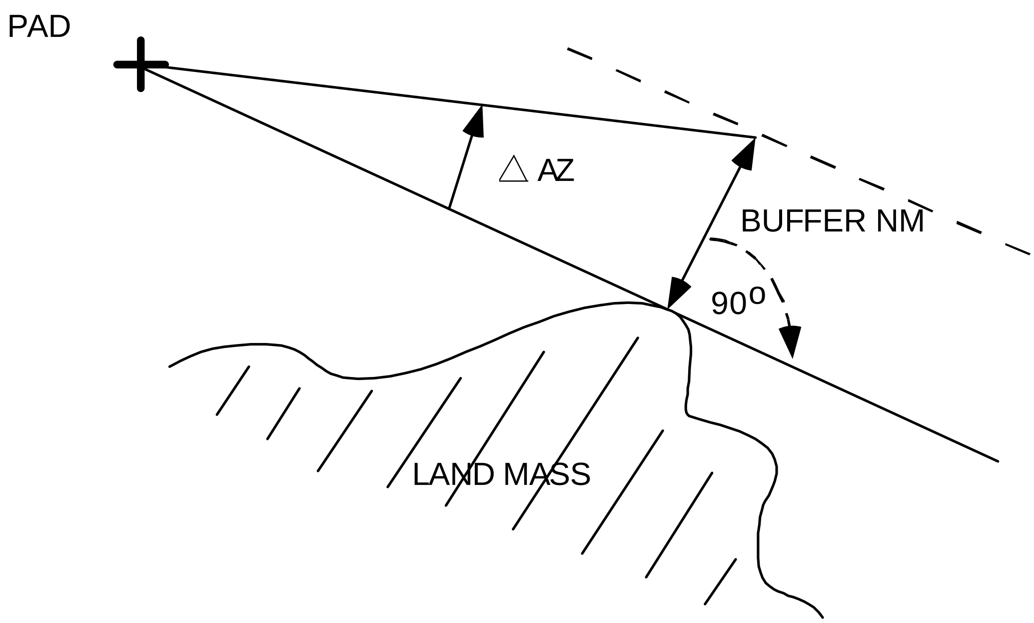

Figure 2 - 15 Buffer

Overflight Corridors. The WFF criteria specify that a vehicle may not overfly a populated area in violation of government or private agreements. Unless the vehicle is in orbit, the probability of land impact must be acceptable when considered as a factor in determining mission approval, and the casualty expectation must be less than the WFF criteria (1.0×10^{-6}). This means establishing flight safety limits to guard against an impact in the area of concern. Figure 2-16 shows a graphical representation of an overflight corridor.

An agreement or the risk of political embarrassment requires that a certain buffer be kept around an island; otherwise, a risk analysis is performed. The land impact probability and the casualty expectation are calculated as described previously. Flight safety azimuth limits are computed and used similar to the azimuth limits for the mainland. In some cases, elevation limits may also apply. The flight elevation angle determines whether the vehicle will overfly or even reach an island. Time is also a factor; an overflight risk only exists during certain segments of the flight. For example, during the early part of a flight from WFF, a rocket does not yet have enough energy to reach Bermuda. Although the rocket flight azimuth is in the corridor at this time, it presents no risk to Bermuda. The IIP display is used to display possible overflight corridors. An ellipse can be drawn around the area to be protected. Overflight corridors can also be shown on an XY present position display.

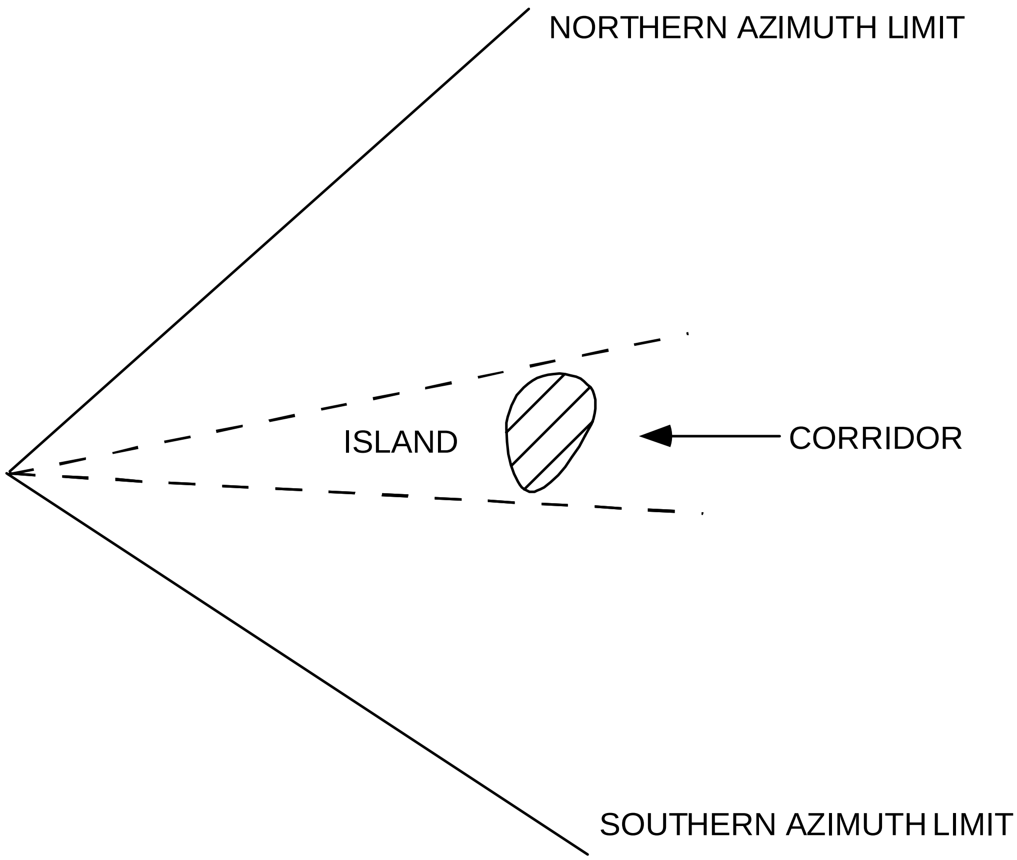

Figure 2 - 16 Example of an Overflight Corridor

Flight Elevation Limits. The flight elevation angle affects the impact range of the rocket as shown in Figures 2-17 and 2-18. For an unguided rocket, the launch elevation angle (Q_E) will determine the nominal impact range. The FSO must ensure that the launch elevation angle will not result in a predicted impact where the risks exceed the safety criteria. Generally, the higher the Q_E, the less the impact range and, consequently, the higher the probability of land impact.

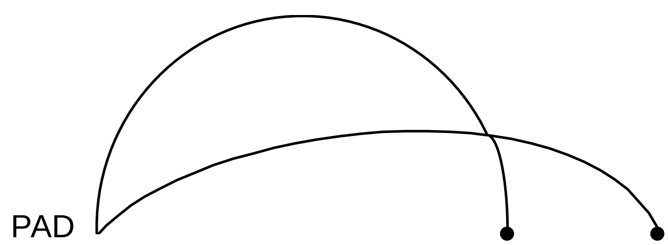

Figure 2 - 17 Launch Elevation Angle

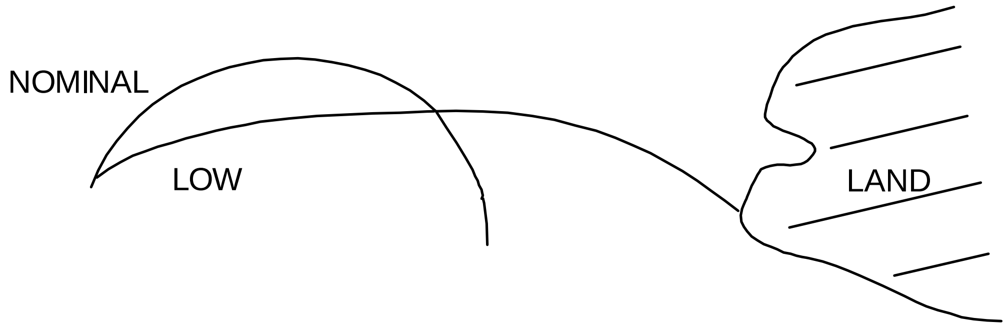

Figure 2 - 18 Effect of Low Elevation Angle

For multistage missiles, the impact areas of each stage must be taken into account and evaluated in a similar manner as described above.

There is also a potential hazard in launching an unguided rocket at high Q_E's near 90^0 (Figure 2-19). The effect of a tail-wind could cause the rocket to pitch "over the shoulder" and fly in the opposite direction of the intended flight path.

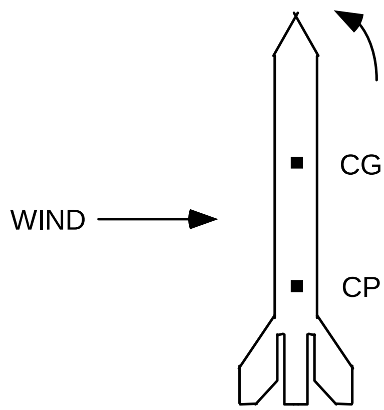

Figure 2 - 19 Unguided Rocket at High Q_E's

Rockets with guidance systems attempt to fly a predetermined flight elevation angle generally resulting in a smaller impact dispersion. The guidance system provides the rocket with the capability to impact outside the planned impact area. In this case, a destruct system is required. The flight safety elevation limits then become the maximum (or minimum) that can exist at the specified times to ensure that the rocket impacts within the planned impact area. The limit is the maximum (or minimum) value of a launch parameter that satisfies the safety criteria.

2.4.2.5.9 Maximum Range. The WFF Flight Safety Analyst determines the maximum range of the rocket to define the land areas potentially at risk for a given mission. For unguided rockets, the range is a function of the launch elevation angle and dispersion as shown in Figure 2-20. As the elevation angle is lowered, the impact range increases until a maximum is reached. If the maximum range of the rocket is less than the distance to the area that needs to be protected, no FTS is required.

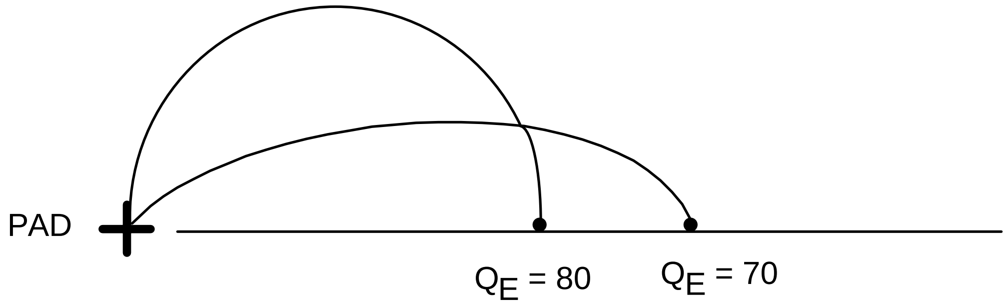

Figure 2 - 20 Maximum Range

For vehicles with guidance and control systems and an FTS, the impact range is defined by the flight elevation angle when command destruct action is taken (Figure 2-21). Therefore, the flight safety limit is based upon the debris impact range corresponding to the worst case flight elevation angle that the vehicle could achieve.

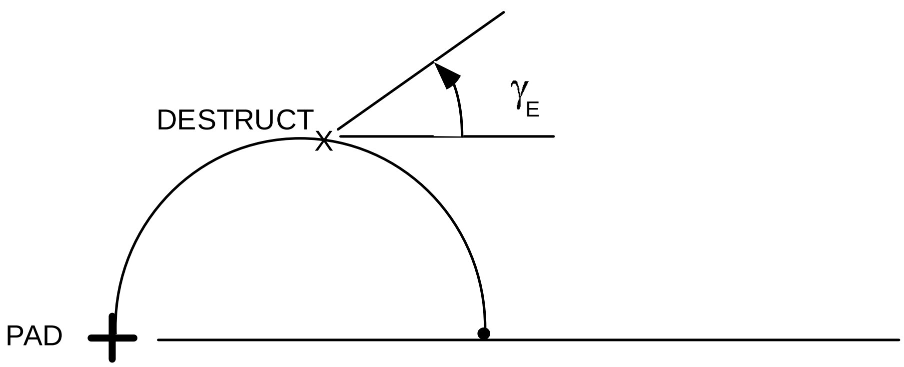

Figure 2 - 21 Impact Range Defined by Flight Elevation Angle

2.4.2.5.10 Guidance Systems. The majority of sounding rockets are unguided vehicles. Their predicted impact locations depend on the launch parameters (azimuth and elevation) and the vehicle dispersion. The mission risk is calculated using the previously presented probability techniques. Some sounding rockets, such as the Aries, use a guidance system. Other rockets with guidance systems include Scout, Vandal, Conestoga, and Pegasus. The guidance system provides control of the vehicle to keep it on its planned flight path. This, in itself, produces a reduction in the vehicle dispersion. The onboard flight computer senses deviations from the planned trajectory and sends commands to the control system to bring the vehicle back towards the planned trajectory.

There are several different types of guidance systems used on vehicles launched from the WFF. Three common types are:

- Gas Jets (Scout, Pegasus)
- Canards (Black Brant, Vandal)
- Thrust Vector Control (Aries, Pegasus)

All of these guidance systems produce forces and moments that cause the vehicle to modify its flight path.

Guidance and control systems provide a vehicle with the capability to turn, allowing the rocket to correct back to its intended trajectory, but, assuming a failure, also allowing the vehicle to turn away from its intended flight path. To safely conduct a mission, it is necessary to establish flight safety limits to protect against an errant vehicle. The capability of a rocket to deviate from its intended flight path is integral in the calculation of these limits. Turn rates are normally expressed in the number of degrees that the vehicle velocity vector can change during a specified time interval. It takes the FSO a certain finite amount of time (usually three to five seconds) to detect a malfunctioning vehicle, determine that the flight safety limits are being exceeded, and initiate the destruct action. Turn rates are calculated to determine the maximum distance that an errant vehicle can traverse during this reaction time.

2.4.2.5.11 Operational Hazard Area. The operational hazard area is that area within which the risk due to impacting object(s) may exceed the established risk criteria. It must be kept clear of ships and aircraft. For unguided launch vehicles, the size of the hazard area is such that the probability of hitting a ship or aircraft just outside the area is less than the accepted probability. For guided vehicles with a destruct system, the destruct limits are calculated such that all impacts are contained within the hazard area.

Impact clearance must be obtained for the operational hazard area. For WFF, clearances are obtained from Fleet Area Control and Surveillance Facility (FACSFAC) for Virginia Capes (VACAPES) areas and from FAA for FAA airspace. Standard procedure at WFF is to increase the operational hazard area (mission dependent) to compensate for changes in launch parameters and for use as a buffer (conservatism). Two separate clearance requests go out, one for aircraft and one for ships.

The operational hazard area for unguided systems is basically a function of the vehicle dispersion. For guided systems, the hazard area is a summation of a number of components that result in a maximum deviation from the nominal flight path:

- Flight Control Corridor - Preprogrammed guidance systems cause the vehicle to fly a predetermined trajectory within a certain variance, usually identified by a one-sigma value.

- Data Source "Error" - The accuracy in which the FSO knows the location of the vehicle (radar/display accuracy).

- Debris Drag Impact - This is the distance that the vehicle debris traverses after destruct has occurred. It is a function of four parameters: altitude, velocity, flight path angle, and the drag coefficient of the debris particle with the furthest impact range. Heavy particles with low drag go the furthest after destruct.

- Buffer - A buffer is a "cushion" factor added to a hazard area for such purposes as to compensate for inaccuracies in reporting the location of ship and air contacts and any uncertainties in the hazard area calculations.

2.4.2.5.12 Launch Hazard Area. The launch hazard area defines the area around the launcher that is potentially at risk from an impacting vehicle. The launch hazard area is implemented to protect against a vehicle failure occurring early in flight before the FSO can ascertain the failure and send a destruct command. As shown in Figure 2-22, the size of the launch hazard area is determined by the worst case (maximum pitch up) vehicle performance until destruct action is taken.

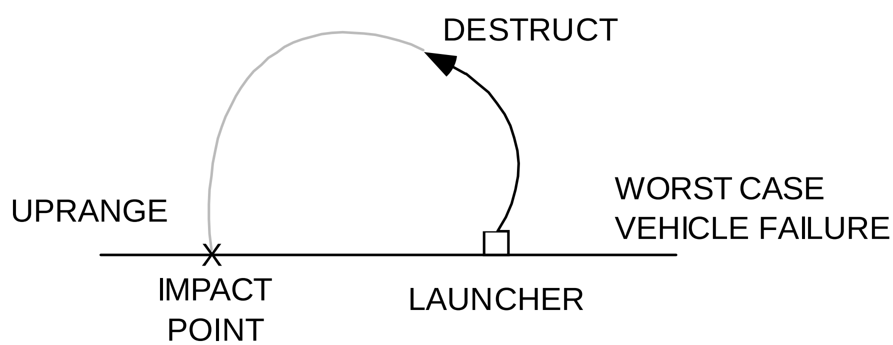

Figure 2 - 22 Worst Case (Maximum Pitch Up) Vehicle Failure

To establish a launch hazard area, the following information must be known:

- How far the vehicle can go within the FSO reaction time,

- Where the pieces will impact if the vehicle is destroyed, and

- If there will be any secondary explosions when the pieces impact.

To answer these questions, WFF safety personnel do an analysis of the flight trajectory using maximum vehicle turn capability. Every five seconds of trajectory is examined to determine where the pieces would impact and what their explosive effect would be if the vehicle were to be destroyed. The result represents the launch hazard area for that particular point in time. The worst case is used as the overall launch hazard area, and anyone within this area at launch must be in a facility capable of withstanding potential hits.

2.4.2.5.13 Aircraft Hazard Area. Missile operations inherently produce a hazard to aircraft in the vicinity of the vehicle or spent stage impact areas. WFF's policy requires that an aircraft hazard area similar to the one shown in Figure 2-23 be established to protect aircraft and passengers against the risk of a vehicle/aircraft impact.

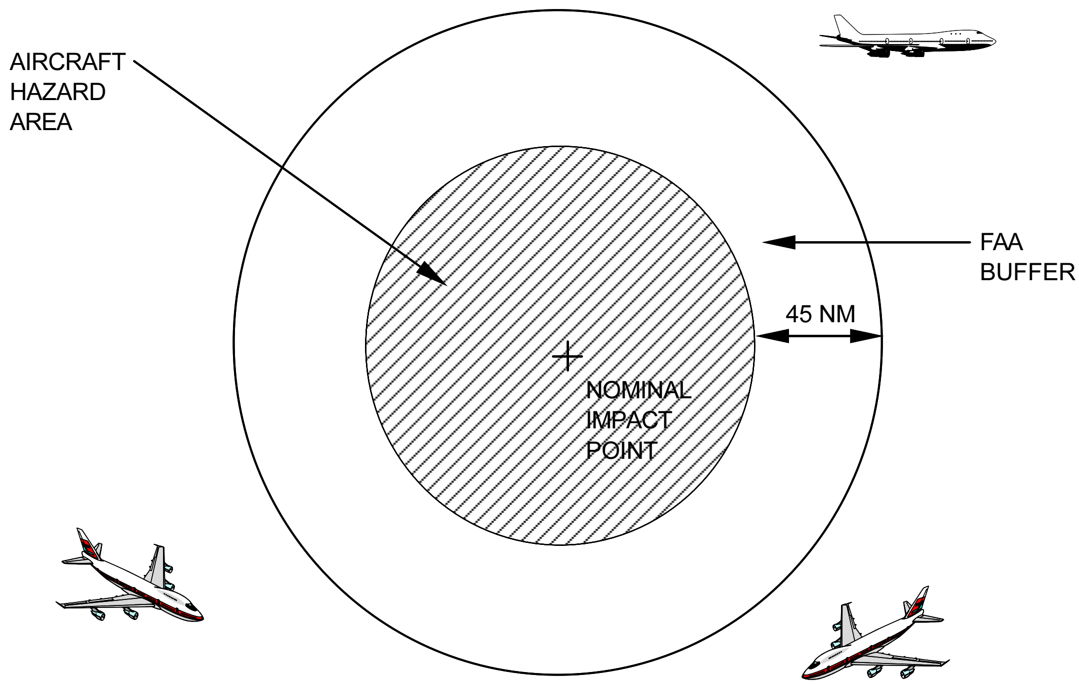

Figure 2 - 23 Aircraft Hazard Area

WFF has an existing Memorandum of Agreement with the FAA that specifies responsibilities and procedures for protecting aircraft during launch operations. This document assigns WFF the responsibility for assessing the hazard to aircraft and for determining the size of the hazard area. The FAA routinely adds 45 nm to the Wallops hazard area to protect against aircraft navigational errors; it is not part of the WFF aircraft hazard area. As stated above, the size of the operational hazard area is based on the aircraft hazard area since this area is larger than the ship hazard area.

Range Safety computes the aircraft hazard area based on the casualty expectancy criteria specified in the Range Safety Manual ($1X10^{-7}$). Use of these criteria can result in large hazard areas for vehicles with large dispersions.

2.4.2.5.14 Orbit Prediction. Orbital parameters can be predicted for a multi-stage launch vehicle once the next-to-last stage burnout parameters are known. This prediction technique assumes a nominal stage performance. There is an orbital injection "window" that the vehicle must pass through if it is going to achieve a satisfactory orbit; i.e., a perigee of at least 50 nautical miles. If the flight elevation angle is too high or too low at stage ignition, the vehicle will not achieve orbit. If it does not achieve orbit, the stage plus payload will impact somewhere on the first pass around the earth. The predicted orbital parameters can be displayed after stage burnout. If the predicted perigee is less than 50 nm, the payload will not achieve a satisfactory orbit and the vehicle is destructed. Typical orbital parameters displayed to the RSO are as follows:

- Velocity (at stage burnout)
- Apogee
- Perigee
- Orbit Inclination
- Latitude (stage impact)
- Longitude (stage impact)

2.4.2.5.15 Collision Avoidance. WFF safety personnel ensure that all manned spacecraft and high value satellites are protected from collision with sounding rockets, expendable launch vehicles, payloads, and other expended items. Collision avoidance (COLA) calculations are performed for any launch vehicles that achieve an altitude of 200 KM or greater. Manned spacecraft must have a minimum separation distance of 200 KM. WFF generally protects high value unmanned satellites by 25 KM. Specific COLA requirements for unmanned satellites are coordinated with the Range user. WFF provides the predicted state vectors at burnout to Space Command. Space Command performs a collision analysis and provides WFF with any launch window "closure" times for the planned operation. A closure is a period of time when the vehicle may not be launched without an unacceptable high probability of impacting spacecraft and/or satellites presently in orbit.

2.4.2.5.16 Aircraft Missions. WFF conducts numerous research and development aircraft flights. In addition to aircraft-related programs, WFF and range users provide support aircraft for rocket operations. Support aircraft perform such functions as surveillance and data relay. Inherent in aircraft operations are the potential hazards to the participants. The Air Worthiness Review Board (ARB) reviews the hazards and risks associated with the proposed mission or any modifications to existing aircraft that may affect its flight worthiness. Operational considerations include airspace, flight profiles, visibility, and aircraft separation distance (altitude and horizontal range). Aircraft operations may also create a hazard for the public. An object dropped from an aircraft or an aircraft crash can produce significant hazards to people on the ground. Other hazards may include low flying aircraft, sonic booms, and eye hazards from operating lasers onboard particular aircraft.

2.4.2.5.17 Computer Programs and Databases. WFF uses a number of computers and many computer programs to support flight safety analyses and operations. Programs are run on the ENCORE mainframe computer, HP 900 Wind Weighting computer, and numerous PCs. A number of databases exist to provide data for the flight safety analysis programs. Some examples are:

- Flight history data for dispersion analyses.
- Map data for impact probability calculations.
- Population data for casualty expectation calculations.
- Aircraft data for aircraft hazard area calculations.

Range Safety uses numerous computer programs to support flight safety analyses and operations. Programs are used in the following basic functional areas:

- 3-Dimensional, 5-D, and 6-D rocket trajectory programs
- Impact probability, probability of destruct, and casualty expectation calculations
- Hazard Area determination
- Rocket dispersion
- Rocket wind weighting
- Real-time predicted impact points

2.4.3 Safety Data, Documentation, and Reviews

The safety data requirements, including the schedule for providing this data, are specified in Section 8.0 of the WFF Range Safety Manual. In practice, the data requirements for most vehicles are a subset of these. Once a project has been initiated at the range, the Flight Safety Analyst must determine what safety analyses must be performed and what data is required to support these analyses. The Flight Safety Analyst also must determine when these analyses should be done and when the data are required in order to furnish timely support. Particular attention is paid to analyses with long lead times.

The official point of contact with the range at WFF is through the Wallops Range Support Manager (RSM) of the Program and Mission Management Division. However, safety personnel normally deal directly with the range user once the initial contacts have been made, and the RSM is kept apprised of the data flow. The types of information required are described in the following sections.

2.4.3.1 Launch Vehicle and Payload Data

The following data is required for the launch vehicle and payload:

Hazardous Electrical Circuits. Range users provide the RSM with two copies of schematic and wiring diagrams of all electrical circuits that include hazardous systems. Range Safety is promptly notified of any changes to hazardous electrical circuits that are made during the course of the program.

Mechanical Systems. Range users provide a description, including technical details and precautions, for all hazardous mechanical systems. Scale drawings are supplied by the user showing the location of all hazardous systems.

Ordnance Devices. For each electro-explosive device (EED), data sheets are provided by the user showing the minimum all-fire current, maximum no-fire current, recommended firing current, normal resistance, pin-to-case resistance, and RF sensitivity characteristics. A technical description of all safe and arm type devices used is provided by the user. For ordnance devices such as rocket motors and shape charges, data sheets are provided that identify the DOD explosive classification, normal output characteristics, composition, and other relevant information required to perform a safety analysis.

Chemicals. The range user provides a description and schematic diagram of chemical systems. All hardware components (tanks, fittings, and valves), and system safety features are defined. A Material Safety Data Sheet for each chemical used on the vehicle is provided to WFF safety.

Pressure Systems. The range user provides a description of all pressure systems used on the vehicle. Technical characteristics, including design burst, proof, and operating pressures, internal volume, and materials of construction are provided.

Radiation Sources. The range user provides data on all ionizing and non-ionizing emitters including frequency of operation, type of emission, type of radiating antenna, and radiating power (both peak and average). The range user also provides data on all optical emitters (lasers) including wavelength, pulse width, pulse repetition frequency, divergence angle, and power output.

Ground Support Systems (GSE). Range users provide schematics, drawings, operational description, technical details, and documentation of certification for all GSE used to support hazardous systems or operations.

2.4.3.2 Operating Procedures

The following procedures are provided:

Hazardous Systems. The range user provides detailed procedures for handling, assembly, and checkout for all hazardous systems (ordnance, mechanical, pressure, chemical) to WFF approximately 75 days prior to launch.

Contingencies. The range user provides contingency procedures to WFF approximately 75 days prior to launch. These procedures include steps to be taken in the event of a launch postponement, launch cancellation, hold or abort, booster ignition failure, unintentional land impact, emergency response, chemical spill cleanup, or any other contingency that may endanger personnel or property.

All approvals for handling, assembly, and checkout of hazardous systems are under the authority of the Chief, Safety Office. Formal approval is required prior to any potentially hazardous operation being performed.

2.4.3.3 Performance and Flight-Worthiness Data Requirements

The data defined in the following paragraphs provide a summary of typical information required to perform a flight safety analysis. The actual data requirements are mission specific and require close coordination between the range user, RSM, and Range Safety.

Launch Vehicles. The range user provides a detailed vehicle description including scaled drawings and operating procedures.

Nominal Trajectory Inputs. The range user provides data in sufficient detail to allow WFF to perform a five degree-of-freedom analysis. The data required consists of the following parameters:

- Mass Properties - weight, inertia, and center of gravity;
- Propulsion - thrust and chamber pressure;
- Aerodynamics - drag, Cna (normal force coefficient), Cma (moment coefficient), Cmq (pitch coefficient), Clp and Cld (lift coefficients);
- Guidance and Control - guidance program, attitude gains, and attitude rate gains;
- Launch Parameters - launcher settings, launch coordinates (earth model), and a sequence of events (ignitions, burnout's, and separation times).

Nominal Trajectory Outputs. The range user provides output data in printed, plotted, and/or computer medium format for each impacting or orbital body. The output data includes:

- Time, velocity, altitude, horizontal range, weight, thrust, drag, dynamic pressure, angle of attack, velocity vector, elevation and azimuth angles, present position and IIP latitude and longitude, position data in x, y, and z, slant range, azimuth and elevation relative to the launcher, and control system forces, moments, and deflections.

- Maximum horizontal range, maximum velocity, and turn rate data.

Range User Data. The range user also provides the following data:

- Stability and dynamics analyses including flexible body, static margins, and a roll rate versus pitching frequency.

- Data that document the results of aeroelastic, structural, and thermal analyses.

- Total dispersion data, either theoretical and/or empirical, in terms of one, two, and three sigma ellipses for all impacting bodies. Range Safety approves all techniques and values of error sources used in the dispersion analysis. A theoretical analysis includes such factors as thrust offset, thrust misalignment, aerodynamic errors, uncompensated winds, launcher misalignments, weight and impulse errors, guidance and control system errors, ignition delay, and any other errors unique to the vehicle. Flight history trajectory data is provided for previous vehicle flights.

- A complete physical and mathematical description of all vehicle guidance and control systems.

- A debris analysis including the technique used and the input parameters used in the analysis. The WFF either performs their own debris analysis or uses the one provided by the user as determined by Range Safety personnel. Range Safety requires chamber pressure and the number and type of debris fragments caused by vehicle breakup. The data for each debris fragment includes the ballistic coefficient, weight, dimensions, drag coefficient, and the incremental velocity imparted by the vehicle breakup.

- A wind effects analysis and documentation on the method used for calculations.

- A gross hazard analysis for critical systems. Range Safety personnel determine what, if any, critical systems require an analysis. The analysis identifies each potential hazard and the preventive measures used to reduce each potential hazard. A risk assessment for those potential hazards that cannot be eliminated by preventive measures is also included.

- Flight profiles including aircraft velocities, altitudes, and separations for multiple aircraft.

- Data on platform instrumentation that is of a hazardous nature; i.e., pressure systems, ordnance, gases, lasers, high-voltage.

Telemetry Data for Vehicles with FTS. The range user has the responsibility to coordinate specific mission telemetry data requirements with Range Safety personnel. If a telemetry requirement is determined to be mandatory a waiver may or may not be granted in accordance with the paragraphs below. Examples of telemetry parameters that are normally required are:

- Command receiver signal strength (AGC) and check channel (command receiver channel 4).
- Inertial Navigation System (INS) Parameters. Inertial position, velocity, and acceleration. Inertial EFG coordinates are preferred. All reference systems shall be defined.
- INS initialization parameters
- Guidance commands, including nozzle deflections in the pitch and yaw axes
- Vehicle attitude data including pitch, yaw, and roll angles and rates
- Motor chamber pressures
- Flight Termination System
- Control circuit status
- External/internal battery voltage
- Safe and Arm status
- Global Positioning Satellite (GPS) position and velocity data

GPS data may not be available due to lack of GPS receivers and thus not required.

2.4.3.4 Waivers

The WFF policy is to avoid the use of deviations or waivers except in extremely rare situations. They will be granted only under unique or compelling circumstances.

A deviation is a variance that authorizes a departure from a particular safety requirement established in the Range Safety Manual where the intent of the requirement is being met through alternate means that provide an equal or greater level of safety.

A waiver is a variance that authorizes departure from a specific safety requirement where an increased level of risk has been accepted.

Waiver requests are submitted to the RSM with identification of affectivity of the request and the requirement that is not being met. Also, a detailed description of the noncompliance and justification for the waiver request must be submitted with supporting documentation to include the reason for the request, analysis of additional risks, proposed methods for mitigating the risks, and supporting technical studies. This documentation is forwarded, in parallel, to the Director of Suborbital Projects and Operations and the Chief, Safety Office. The Chief, Safety Office, develops a Safety Analysis Report, recommending approval or disapproval, for the Director's approval for systems that exceed established risk criteria. Normally, waivers are granted for only one mission or a specific number of missions or mission activities. If risk criteria are not exceeded, but an FTS requirement is not being met, the Chief, Safety Office has approval authority.

In practice, the noncompliance is normally introduced as a problem at one of the early design reviews. It is accepted for review by a WFF representative (for example the Ground Safety or Flight safety Analyst) and the problem is resolved. The noncompliance is either approved as meeting the intent of the requirement or is submitted as a formal waiver request. As part of the official documentation process, the range user must provide a copy of any waiver for the launch vehicle or payload granted by another Range.

2.4.3.5 Reviews

WFF and the commercial range user personnel participate in several reviews prior to conducting the launch countdown and launch of a vehicle. These reviews consist of the Range Readiness Review (RRR), Flight Readiness Review (FRR), Pre-Mission Review/Briefing (PMR/B), and Post-Launch Review (PLR).

The RRR is internal to WFF and provides the means for determining the readiness of the range to support the specific operation. This review occurs approximately two weeks prior to the scheduled operation and is usually chaired by a representative of the Range and Mission Management Office.

The FRR is conducted for orbital operations and occurs approximately three days prior to the scheduled vehicle launch date. This activity is jointly chaired by representatives of the Suborbital Projects and Operations Directorate and the Office of Flight Assurance. The range user is an active participant in this review.

The PMR/B is usually held the day before the scheduled launch of the vehicle. The purpose of this review is to assure that all action items resulting from the FRR are closed and all parties are ready to support launch operations. Personnel from both WFF divisions finalize the plans for conducting the operation, i.e., communications procedures, Range Safety and range user GO-NO GO criteria, flight safety mission rules, and mandatory safety items required to be operational prior to launch.

The PLR is conducted immediately following the launch, or at no later than 24 hours after launch, and is attended by key range and user personnel. The purpose of this review is to assess the overall mission countdown and launch vehicle flight, and to identify any anomalies that may have occurred.

2.4.3.6 Safety Analysis Report

A Safety Analysis Report (SAR) is an analysis of the operational safety procedures and an assessment of the risk in conducting a program. It identifies the safety hazards created by the conduct of the project, the preventive measures to be employed to minimize the risk, and assesses the resulting risk level. SARs are normally done when it is anticipated that the risk level will exceed the safety criteria, for some special or unusual projects, or for certain international operations.

A risk assessment is a scaled down version of a SAR that is used to assess the risk for a specific mission. Often, a comprehensive SAR has previously been done for the program. If the results of the SAR/risk assessment show a risk level higher than the flight safety criteria, a safety waiver must be obtained. In this process, the scientific value or national importance of the mission is weighed against the increased risk in conducting the operation.

2.4.3.7 Mission Rules

Mission Rules identify unique destruct criteria and any special user requirements that are not covered elsewhere (such as safing the FTS when the launch vehicle is no longer thrusting). They are developed for each mission by the Safety Office, coordinated with the Range and Mission Management Office and the range user, and documented in the Flight Safety Plan and the Operations and Safety Directive. Mission Rules normally consist of two parts: standard mission rules, which could apply to all launch vehicles with a FTS, and unique mission rules, which are tailored for a specific launch vehicle. On launch day, the RSO has the authority to waive a particular mission rule if, in his judgment, exposure to the public domain will not exceed casualty expectation criteria (1×10^{-6}). Examples of standard mission rules are as follows:

- Violation of fixed “destruct lines” will result in termination of vehicle flight.
- Violation of immediate launch area present position destruct criteria will result in termination of vehicle flight.
- If the vehicle performance is “Obviously Erratic” (out of control) and further flight is likely to increase the hazard, the RSO, based on his judgment, has the authority to terminate flight. This could occur by either interpretation of displayed data or by reacting to verbal calls from the Skyscreen Observer.
- If vehicle tracking status becomes “unknown” and the capability to violate an ILL exists, the RSO will make a judgment whether or not to terminate flight. If the vehicle performance has been normal after launch for an

extended period of flight (which is not defined) prior to becoming unknown, the RSO may elect to allow the flight to continue. The RSO must evaluate all performance parameters and available data and determine whether mission rules can be violated or if potential exposure to the public domain necessitates destruction of the vehicle.

2.4.3.8 Flight Safety Plan

A Flight Safety Plan is published for each launch operation and serves as the working document for Range Safety personnel. It contains such information as predicted impacts, dispersion, aircraft hazard area, flight limits, wind limits, and destruct criteria. For operations at WFF, the Flight Safety Plan is incorporated into the Operations and Safety Directive.

2.4.3.9 Operations and Safety Directive

An Operations and Safety Directive (OSD) is published for each operation conducted at WFF. It includes a description of the operation being performed, support requirements, Go/No-Go requirements, safety plans, and a countdown.

2.4.3.10 Approval Cycle

From a safety standpoint, the approval cycle for the launch of a commercial launch vehicle starts with a project initiation meeting that takes place after a commercial mission has been accepted for launch at the WFF and standard agreements between NASA and the range user have been approved. At the meeting, the mission objectives are defined and a description of the launch vehicle and proposed orbit are presented by the range user. After the meeting, a formal memo is issued by WFF and the range user documenting the results of the meeting.

For launch vehicles or payload systems not previously launched from WFF, all final data must be supplied no later than 90 days prior to the operation. However, for launch vehicles or payload systems previously launched from WFF, final data must be supplied no later than 60 days prior to the operation. Preliminary data for these systems must be submitted no later than 120 days prior to the operation. If deadlines are not met, Range Safety may not be able to prepare all necessary safety plans in time to support a proposed flight. In every case, the mission will not be conducted until adequate safety preparations are made.

Mission specific schedules will be defined on a case-by-case basis. The typical significant events required to complete the approval cycle occur at the following approximate times:

Prior to the Preliminary Design Review (PDR), Safety Technical Interchange Meetings (TIMs) are held to address specific safety issues. At these meetings, formal presentations of safety issues are made by the range user and WFF Range

Safety personnel. Then, a memo is issued by the range user documenting the status/resolutions of the safety issues discussed.

No later than L-18 months (L-9 months for sounding rockets), a PDR is held with the range user providing the following information:

- Preliminary Safety Analysis
- Gross Hazard Analysis
- Design documents and drawings
- Preliminary trajectory definition

At PDR plus 60 days (PDR plus 30 days for sounding rockets), a preliminary Safety Data Package (SDP) is provided for review and for Safety Plan development. This package is in response to the data requirements in the Range Safety Manual. In the same time frame, Safety TIMs are held for the purpose of discussing the SDP and for the range user to present trajectory data and safety analyses. A formal memo is issued by the range user documenting status/resolutions.

No later than L-12 months (L-6 months for sounding rockets), a Critical Design Review (CDR) is held whereby the range user presents the final design configuration. At this review, preliminary safety approval is given on subsystems. Of particular interest to Range Safety is the design of the FTS. In this same time frame, Safety TIMs are held to resolve action items from the CDR and any outstanding safety issues. The range user identifies design changes, operational methods, and testing. After the meetings, a formal memo is issued documenting resolution of issues.

At CDR plus 60 days (CDR plus 30 days for sounding rockets), Operational Support Systems TIMs are held at which WFF safety representatives present real-time data requirements.

At L-75 days, the range user provides the final Safety Data Package and the final procedures for all hazardous operations for review and approval by Range Safety. In this same time frame, a system safety action item resolution meeting is held where an attempt is made to close out any safety action items remaining at this time. A formal WFF memo documents the results.

No later than L-60 days, the range user provides the final trajectory data tape and inputs to WFF.

At L-45 days, WFF provides a letter to the range user approving hazardous operating procedures.

At L-30 days, a mission safety review is held by the range user and Range Safety for the final closure of safety action items resulting in a formal memo documenting Mission Safety Readiness.

At L-21 days, the Operations and Safety Directive is issued by the WFF, providing the Ground Safety Plan, the Flight Safety Plan, and Go/No-Go items. In addition, WFF defines FTS test plans and certification documentation.

At L-14 days, a Mission Readiness Review is held by the WFF RSM to determine the readiness of the range, the launch vehicle, and the supporting launch site.

No later than L-3 days, a FRR is held to assess the range user's readiness for launch and to assess the readiness of the WFF to support the launch.

At L-2 days, a Launch Readiness Review is held by the WFF RSM to review the results of all prelaunch testing and certification.

On Launch Day, if safety requirements are satisfied, such as weather constraints, final FTS checks, hazardous areas cleared, a final GO FOR LAUNCH is given by the RSO. A graphical representation of the approval cycle coincides with the data requirements flow, as shown in Table 2-1, para. 2.4.2.5.

2.4.4 Range Safety Launch Operations

This part of Section 2.0 describes the Range Safety responsibility for launch operations conducted at WFF. It includes the requirements for obtaining clearance to launch, a definition of weather constraints, and a description of the Range Safety System, as well as the activities necessary for the proper conduct of operations.

2.4.4.1 Range Safety Operations Responsibilities

The Chief, Safety Office serves as the Program Safety Officer and reports directly to the Director of Suborbital Projects and Operations. Therefore, the Safety Office performs a staff function independent of operations. The RSO is responsible for ensuring that all flight safety criteria are satisfied prior to and during an operation. Range Safety personnel review a proposed operation, perform a flight safety analysis, issue a flight safety plan, and monitor an operation to ensure that the safety limits and procedures are followed.

Prior to launch, the FSO is responsible for ensuring that the vehicle has been wind weighted properly (sounding rockets), the launcher settings satisfy the flight limits (sounding rockets), the weather conditions meet the safety requirements, and that all flight safety impact criteria are satisfied. For vehicles with an FTS , an FSO is utilized and has the following responsibilities: Prior to launch, the FSO ensures that all command, tracking, telemetry, computer, data display, and communications systems are operational for launch. After launch, the FSO monitors the flight of the vehicle and terminates flight if and when the vehicle violates the flight safety limits.

2.4.4.2 Clearance

The impact areas and the airspace above the operational areas are generally controlled or owned by other organizations, such as the Navy or the FAA. Permission to impact in, or fly over, these areas must be obtained from the appropriate organization. WFF determines the size and location of the operational hazard areas and then schedules the use of these areas with the controlling organization.

2.4.4.3 Surveillance

WFF is responsible for the surveillance of operational areas to ensure that the WFF safety criteria are satisfied. Ship surveillance is conducted of the impact areas in the VACAPES area by aircraft and radar. The probability of impacting a ship is then calculated. Surveillance is usually not performed for oceanic impacts because of the small ship density far out to sea.

> NOTE: The VACAPES is an irregularly shaped area that extends from a point located at 34^0 14^1 N Latitude and 74^0 0^1 W Longitude up to the 38^0 0^1 N Latitude line. It is bounded on the west by a line that parallels the coast at a distance of 3 miles offshore, and is bounded on the east by the 72^0 40^1 W Longitude line. It contains approximately 30,000 nm^2.

The FAA and the Navy keep aircraft that they control out of the aircraft hazard area during launch operations. WFF performs surveillance for other aircraft in the vicinity of the launch area and over the VACAPES area within range of the ASR-7 radar. For WFF air-launched vehicles, the FAA, in conjunction with the Wallops Range Control Center, provides control of the carrier aircraft movements during a mission.

2.4.4.4 Weather

Weather forecasters give daily weather briefings and are available to support operations as required. The forecaster advises the Range when there are lightning storms, or the potential for lightning exists, in the Wallops area. The forecaster can also be called upon to discuss the likelihood of achieving the required meteorological conditions for an operation. Wind data can be obtained from radiosondes launched every morning and evening. If required, radiosonde data can be obtained from other sites around the country to ensure that weather criteria stated in the WFF Range Safety Manual are satisfied.

Weather can have a significant impact on safety operations, such as the effect on the trajectory of a rocket. Prelaunch winds (initially taken at approximately three hours prior to launch) are used to determine the launch azimuth and the launch elevation angle that will result in the vehicle flying the desired trajectory. High or gusty winds (on the order of 30-35 mph or gusts above 45 mph) may make it unsafe to launch. Even for guided launch vehicles, the winds may get so strong that they saturate the vehicle guidance system.

A launch vehicle is normally wind-corrected so that the desired trajectory is achieved and the predicted vehicle impact of the last stage is in the planned area. However, this may not result in the booster stage impact being in its planned impact area. Separate wind correction and drift calculations must be made to determine the booster impact location, and to ensure that it is in a safe area. The following weather constraint is used to determine launch readiness:

Do not launch if the planned flight path will carry the vehicle within five nautical miles (nm) of any cloud capable of producing lightning that might strike the vehicle.

The weather forecaster will use the following data in locating electrified clouds:

a. Locations of naturally occurring lightning

b. Surface electrical field intensity at the launch area

c. Horizontal and vertical radar reflectivity structure of clouds within 100 nm of the launch area

d. Temperature profile of the atmosphere

WFF has the necessary resources to obtain this data. Cloud-to-ground lightning can be located by the National Lightning Data Network. Intra-cloud and inter-cloud lightning can be located by the Lightning Detection and Ranging System and/or the UHF radar. Electric fields intensities can be measured by the Electric Field Mill System. Radar data is available from the National Weather Service radars and the SPANDAR radar, and the temperature profiles are available from daily soundings.

Besides using these resources at WFF, the forecaster will use the Launch Commit Criteria developed for Shuttle as a guideline, remembering that:

a. These guidelines are for STS operations and so are necessarily very conservative. Therefore, some of the cloud types identified may not always be sufficiently electrified as to pose a hazard.

b. These guidelines do not account for any climatic differences between GSFC/WFF and KSC.

The RSO may hold at any time based on the instability of the weather, or any other hazardous weather conditions, even when weather constraints are not violated.

2.4.4.5 Range Safety System

The Range Safety System consists of all equipment, software, and personnel required to perform the safety function for an operation. The components and level of redundancy for the Range Safety System differ significantly depending on whether the vehicle has an FTS. For vehicles with an FTS, the fundamental requirement for the system is that no single failure point will negate the RSO's ability to determine vehicle performance, detect a violation of flight termination criteria, transmit abort commands, or have the vehicle receive and process those abort commands throughout all phases of powered flight that may hazard life or property. The systems that are required to satisfy this requirement are designated mandatory.

During an operation, the RSO has two major decisions to make: whether Safety is GO FOR LAUNCH with inputs from the FSO and GSO., and whether to terminate the flight of the vehicle. Data sources and displays available to the safety team for decision making are:

- Radar
- Telemetry
- Radar and telemetry data from the real-time Range Safety computer
- Skyscreens
- Video
- Frequency monitoring
- Weather data
- Ship reports
- Time

The RSO must either be in position to see the data displays or be in communication with safety support personnel who are observing the data. The information must be presented in a format that is simple to evaluate and be available in a timely manner. Also, the information must be communicated such that the RSO is not over-saturated with data. A Range Safety "smart" system in which computers collect, analyze, and interpret data for the RSO is currently under development and should enhance the RSO decision-making process.

2.4.4.6 Command System

The command system is the primary system used by the RSO to contain the flight of a launch vehicle. The Wallops command system is used to uplink the command signals to the launch vehicle. It is most commonly used to send a flight termination command; however, the system can be used to uplink such commands as payload deployment. The major components of the command system are as follows:

- The RSO Control Panel allows the RSO to initiate prelaunch test and checkout functions and to send arm/destruct commands, if necessary, during the vehicle flight. This panel is located at the RSO console in the Wallops Integrated Control Center (WICC).

- RSO commands are relayed from the RCC command panel to the Command Transmitter site on Wallops Island. Other remote sites such as Bermuda can also be used. NASA Communications (NASCOM) provides, upon request from WFF, two independent, hard-wire paths from the console to Bermuda or Coquina. One line is tied to System 1 and the other line to the redundant System 2.

- The Command Receiver onboard the vehicle receives the signal from the command transmitter and initiates the indicated action.

- The Frequency Monitoring component of the command system provides continuous status of the command transmitter, and monitors the mission frequency to determine if there is any RF interference.

The FSO and GSO perform several pre-launch checks to verify the readiness of the FTS:

- Command Receiver Drop-out Test to verify that the command receivers will not drop out during flight.

- Command Transmitter Confidence Test to verify that the FSO command panel and the command transmitter are functioning properly.

- FTS Test to verify that the entire FTS, ground and airborne, is functioning properly.

2.4.4.7 Mobile Range

As described in Section 1.0 of this Report, WFF has the capability to conduct mobile campaigns from locations world-wide. All of the necessary instrumentation to support an operation, such as radar, telemetry, and command destruct, can be deployed to a remote site. Site selection criteria for mobile equipment has evolved from experience gained at the WFF.

A link analysis is performed for fixed station command destruct, telemetry, and radar sites that includes established safety margins (such as 12 dB for command destruct). If the link analysis indicates periods of unacceptable margins, another link analysis is performed using mobile equipment located at potential sites to fill in the unacceptable margins. Experience in performing these analyses has resulted in selecting sites for mobile equipment that have aspect angles of 25 degrees or greater to compensate for, as an example, flame attenuation effects at the launch vehicle. Mobile equipment is required to meet the same certification and testing requirements as the fixed WFF sites.

Mobile campaigns have been conducted in places such as Alaska, Kwajalein, Australia, Brazil, Puerto Rico, and Peru. Mobile equipment may also be deployed downrange to Coquina, located near Cape Hatteras, to support a launch from Wallops Island which might not have adequate coverage from the WFF fixed sites. Range Safety sends an RSO and a wind weighter, if necessary, on a mobile campaign. The RSO is responsible for planning the participation of Range Safety personnel and equipment required to support a given mobile campaign.

2.4.4.8 Prelaunch Dress Rehearsals

To ensure proper coordination between the range user and range support during countdown and launch operations, WFF requires that a dress rehearsal be accomplished prior to the actual launch countdown. This operation closely duplicates the actual countdown, with simulators installed in the launch vehicle ignition circuits. The operation is terminated in the plus count where backout and safing procedures are exercised. During the dress rehearsal, the airborne FTS is tested with the ground transmitters and the launch danger area is cleared as it would be for an actual launch. A dress rehearsal is successful if it is completed without any failures, either on the launch vehicle or in the range support equipment, and there is no breakdown in coordination between the range user and range support.

2.4.4.9 Launch Operations Constraints

During launch operations, prior to liftoff, the RSO will not provide a GO FOR LAUNCH until standard safety criteria are met and mandatory, certified equipment and sensors are supporting and operational. After the RSO has provided the GO FOR LAUNCH, should any safety criteria be violated or any mandatory systems fail, the RSO will call a HOLD on the appropriate communication channel. This hold criteria applies to all elements of the missile flight control system. Go/No Go criteria and flight termination criteria are tailored for each launch vehicle, coordinated with the range user, and published in the Operations and Safety Directive. Standard safety criteria for holding a launch are as follows:

- When an unauthorized ship will be in the shipping hazard area at launch time.
- When unauthorized aircraft will be within restricted airspace or in the launch area at liftoff.
- When any emergency arises regarding aircraft, ships, or vehicles responding to emergency situations.
- When mandatory equipment is not available to support the launch.

NOTE: The equipment that is mandatory for launch is determined by the RSO and is incorporated in the Operations and Safety Directive which is published for each operation. The mandatory equipment may vary from launch to launch.

- When the RSO has any reason to believe that any component of the FTS is not operating properly, whether the problem is with airborne equipment or ground equipment.
- When the RSO does not have clear and convincing evidence that weather constraints are not violated. Even when constraints are not violated, if any other hazardous weather conditions exist, the RSO may hold at any time based on the instability of the weather.
- When the countdown is proceeding without the proper checks or necessary information needed by the RSO.
- When, for any reason, the RSO believes that the launch cannot be made with adequate provisions for protection of life and property; i.e., conflicting information.

2.4.4.10 Duty-Time Policy

Limits on duty time are necessary for personnel health and safety reasons, and are considered important to the maintenance of quality on-the-job performance. Supervisors and managers plan and schedule work to meet the following conditions, which apply to activities at WFF and off-site locations:

a. Duty-Time Limits

Sixteen hours per work period,

Seventy-two hours per 7-day period, and

Thirteen consecutive work days.

Eight hours minimum off-duty time required between work periods, except at least 10 hours required when work period exceeds 12 hours.

b. Waiver Authority

Requests for waivers of duty-time guidelines and limits for WFF Test Range operations are referred to the Director of the Suborbital Projects and Operations Directorate. For off-range campaigns/field operations, the campaign manager/official-in-charge can authorize the following:

(1) Work exceeding the duty-time guidelines, up to the limits, as considered necessary and appropriate.

(2) Work exceeding the duty-time limit of 16 hours per work period, up to a maximum of 20 hours, to meet mission critical requirements, once during a campaign/field operation.

(3) Work exceeding the duty-time limits of 72 hours per 7-day period, up to a maximum of 84 hours per 7-day period, once during a campaign/field operation.

Otherwise, the campaign manager/official-in-charge will request approval from his/her division chief prior to scheduling duty time exceeding the limits established in b. above. Any waiver of the duty-time limits is documented, and the information maintained in the appropriate division office for future reference.

2.4.4.11 Launch Operations Coordination

WFF coordinates their launch operations through the following actions:

- Projects are placed on the active schedule upon acceptance by the Director, SPOD;
- All operations are scheduled by the RSM through the office of the Test Director;
- The use of the VACAPES surface and sea operations areas is coordinated with the US Navy, FACSFAC, and is scheduled on Thursday, two weeks prior to the operation. The schedule is published on Friday of the week prior to the operation.
- The airspace to be used is scheduled with the FAA Center, NY, and is coordinated with the FAA Center, Washington, two weeks prior to the operation.

2.4.5 Personnel Training and Certification

The mission-essential personnel who support commercial launch operations at WFF and their certification and training are described in the following paragraphs:

2.4.5.1 Mission-Essential Personnel

Within the limits of their jurisdiction as defined in GMI 1771.1, the Test Director, Range Safety Officer, Range Support Manager, Flight Safety Officer, Ground Safety Officer and Operations Safety Supervisor share responsibility for the safe conduct of operations associated with a mission.

Test Director. The TD has authority over all operations conducted on the WFF Test Range. The TD is responsible for ensuring that all range policy, criteria, and external agreements are satisfied, including coordination of airspace requirements with the FAA and clearance of the VACAPES with the FACSFAC. The TD is the only person with authority to resume the countdown after a HOLD has been declared.

Range Safety Officer. The RSO is responsible for ensuring that WFF safety policy, criteria, and procedures are not violated during operations, and ensuring that risks are understood and are within acceptable limits. The RSO has authority to stop work, hold a launch, or terminate a mission in flight (FTS) if necessary. The RSO keeps the TD and RSM informed of safety status that could affect launch operations.

Range Support Manager. The RSM is responsible for coordinating and directing project activities as necessary during countdowns. The RSM informs the TD and RSO of project status details and keeps the project personnel properly informed of range operational status. The RSM also serves as Assistant TD.

Operations Safety Supervisor. The OSS is appointed for all hazardous launch vehicle operations and is the on-scene Safety Office representative for all hazardous operations as well as the monitor for the installation and checkout of the FTS. The OSS may come from various WFF organizations depending on the specific requirements of each program. The Director, Suborbital Projects, has the authority to delegate this responsibility to a NASA contractor or to range user personnel, if deemed appropriate. The basic duties of an OSS are as follows:

- Implement the Ground Safety Program for potentially hazardous operations;
- Identify the hazardous state of potentially hazardous operations;
- Administer compliance with applicable Range Safety plans, approved safety standards, or approved procedures;
- Maintain close coordination with the RSO and TD concerning policies and procedures;
- Notify the RSO and TD immediately of any handling malfunction or other incident creating or contributing to a hazardous condition;
- Call for a HOLD to a range user operation whenever that operation fails to conform to safety standards, or whenever difficulty is encountered in performing approved hazardous procedures or operations;
- Ensure all hazardous operations are in compliance with approved safety plans and procedures.

2.4.5.2 Training and Certification

Training and certification for all real-time safety-essential personnel such as the TD, RSM, FSO, GSO and OSS who support the RSO during pre-launch preparations, countdown, and launch are normally conducted by on-the-job training. Trainees are assigned to an experienced, qualified operator who acts as a training supervisor to instruct and monitor the trainee’s progress for a period of approximately six months to a year, depending on the trainee’s experience, background, and the complexity of the job. When the training program is completed and the trainee is considered qualified, his position description is changed to reflect the qualification. Training requirements are vehicle/program dependent.

For the TD and the RSM, when a trainee is considered qualified by his training supervisor, a board consisting of key WFF managers reviews their qualifications and certifies them to conduct a particular class of mission. The board interviews the trainee, reviews his experience and training, and decides if he is qualified or needs further training. If he is considered qualified, he joins a list of personnel who are certified to perform the particular class of operation for which he was trained.

The OSS is normally selected from highly qualified personnel with several years experience in the Safety office who is cross-trained and recommended for certification by the Chief, Safety Office.

System Operators. Personnel who operate systems in support of commercial launch operations, such as command destruct, telemetry, and radar, are hired as experienced operators or receive on-the-job training at the WFF. Mobile Range operators receive training on identical equipment and are certified as fully qualified before they are allowed to participate in mobile operations.

On-the-job training programs may vary somewhat among the different offices due to the differences in responsibilities, however, they are essentially the same. Follow-on training is conducted on a continuing basis in order to keep abreast of system improvements and for cross-training and upgrade to other classes of operation. The authority to train and certify personnel is delegated from the Director to the Chief. Safety Office. The Chief, Safety Office may further delegate the authority to a Group Leader responsible for the supporting activity.

FSO TRAINING - A detailed description of the FSO qualifications, training, and certification is provided below.

Qualifications. The desired background requirements for a potential RSO are as follows:

- Grade: Currently only GS-12, and above, civilians are selected to serve as FSO’s for orbital missions.
- Education: Should have a Bachelor's degree, preferably a master's, in some field of engineering or possess equivalent technical experience.
- Experience: Should have a background in missile, space, or aircraft operations requiring real-time decision making.

Training Program. The training program ensures that candidate FSO’s are properly trained and serves as a documented record of the trainee’s progress and performance. The purpose of the training plan is to thoroughly familiarize the trainee with the WFF flight safety philosophy and methodologies. The training is tailored for the prospective FSO who will be performing flight safety analyses on a regular basis. The GSFC/WFF flight safety criteria are presented, and the analysis techniques are provided that are used to determine whether these criteria are satisfied. Emphasis is placed on learning by doing, and the trainee is given regular assignments to perform flight safety analyses and to document the results. Prior to completion of training, the trainee has the opportunity to experience FSO simulations at the FSO console in the WICC.

Certification and Checkout. Upon completion of the formal FSO schooling that includes an examination given to test responses, trainees are issued a certificate of accomplishment by the Chief, Safety Office, to show they are certified eligible to sit on consoles and be part of the Range Safety team. In addition, the position description is changed to include the duties of the FSO.

Under the supervision of an experienced FSO, newly qualified FSO's must perform in a manner consistent with Range Safety policies and procedures. They are evaluated and a determination is made as to whether or not additional training is required. Failure mode simulations are training scenarios for the FSO's. They are presented with simulated mission scenarios at the FSO console in the WICC. Various vehicle and data system failure modes are provided and presented. The ability of the FSO's to make the correct decisions are evaluated by the training coordinator assigned for that mission. This training is provided on a periodic basis for currently certified FSO's and is driven by the launch mission schedule.

2.4.6 WFF Interfaces

To operate successfully, WFF maintains interfaces with a number of different entities. The principle ones are described below.

2.4.6.1 Outside Agencies Interfaces

National Ranges. WFF provides operational support for and uses other national range resources for commercial space activities. Past launch missions have been conducted where WFF served as the lead range with initial Range Safety support being provided by ER safety personnel. Transfer of safety support to WFF occurred during the actual flight of the vehicle when WFF gained reliable tracking and FTS capability. WFF also provides tracking support to the ER for missions launched on northern azimuths (high inclination) as required. In addition, WFF personnel have provided safety support to Vandenberg Air Force Base in the processing and launch of the Pegasus launch vehicle.

WFF coordinates with other ranges for the procurement of FTS command destruct receivers and supports a cooperative effort to standardize FTS requirements. WFF furnishes command transmitter, radar, and telemetry tracking support for launches from the Eastern Range and provides off-base launch support for vehicles launched from other states (California, New Mexico, and Alaska) or countries (Peru, Brazil, Australia, and Puerto Rico).

Federal Aviation Administration. WFF coordinates activities in restricted areas with the FAA for all aircraft coming into the WFF to ensure these aircraft are not endangered during launch operations (See 2.4.2.5.11). Mission support aircraft, are also under the purview of the FAA and require WFF notification of their intended flight path and operational areas.

Department of Transportation. WFF coordinates with the Department of Transportation in the shipment of hazardous rocket components and explosives to the WFF range.

Defense Mapping Agency. This agency is responsible for providing Notice to Mariners (NOTMARS) for oceanic impacts occurring outside the Virginia Capes (VACAPES) warning areas.

Space Command. Wallops coordinates with Space Command for Collision Avoidance (COLA) operations to ensure that all manned spacecraft and high value satellites are protected from collision with WFF launch vehicles. Calculations are performed for any launch vehicle that achieves an altitude of 200 KM or greater. WFF provides the predicted state vectors at burnout to Space Command who performs a collision analysis and provides WFF with any “closures” for the operation. A closure is a period of time when the rocket may not be launched due to violation of Range Safety criteria.

Fleet Area Control and Surveillance Facility (FACSFAC). This facility provides scheduling and monitoring of Virginia Capes (VACAPES) operating areas for WFF launch operations. At the request of WFF, they are responsible for issuing Notice to Airmen (NOTAMS) and Notice to Mariners (NOTMARS) inside warning areas immediately adjacent to WFF. All impacts outside VACAPES require clearance from the FAA. WFF is responsible for obtaining this clearance.

Coast Guard. The Coast Guard provides assistance during launch activities in range clearance and payload recovery.

2.4.6.2 Internal Interfaces

Air Worthiness Review Board. When required, WFF Range Safety personnel coordinate with an Air Worthiness Review Board (ARB) to ensure safe operation of aircraft on the WFF range. This includes modifications to existing WFF aircraft or operation of commercial aircraft. Privately-owned commercial aircraft are not covered by NASA requirements documents and must be evaluated independently by WFF personnel (ARB). The primary concern is that the operation of the aircraft does not pose any risks to NASA personnel, facilities, or to the general public that is greater than the risks posed by NASA/WFF owned aircraft.

After a determination is made, a letter is signed by the Chief, Range and Mission Management Office that indicates acceptance or rejection of the aircraft to operate on the WFF range.

Mission Support Aircraft. WFF Safety personnel interface with the Aviation Safety Officer to ensure safe operation of all mission support aircraft required for launch activities. This includes chase and surveillance aircraft.

Range User. WFF personnel coordinate mission support requirements, documentation, operations, safety requirements, personnel, technical meetings, waiver requests, and failure/anomaly investigations with the range user.

2.4.7 Range User Responsibilities and Requirements

To ensure that operations are conducted in a safe and cost-effective manner, WFF has defined range user responsibilities and requirements for operating at WFF. They are described below:

Range User Responsibilities. At WFF, range users are responsible for the following:

- Range users must adhere to all requirements established in the WFF Range Safety Manual.
- Range users must adhere to the directions issued by the TD, RSO, and the OSS.
- Range users must review all vehicle and payload operations with the OSS.
- Range users must obtain permission from the OSS before conducting any operation in assembly, test, or launch areas.
- Range users must identify active essential personnel for each operation to ensure maximum personnel limits that have been set by safety are not exceeded.
- RF radiation on WFF is controlled through the WICC to ensure that RF limits, as stated in the Range Safety Manual, are not exceeded, and to preclude possible interference with other transmitters. Range users must obtain permission through the OSS before any RF transmitters can be switched on.
- The Ground Safety Plan defines danger areas clearance requirements and personnel restrictions for all potentially hazardous operations. Range users are responsible for complying with these restrictions.
- Range user personnel engaged in potentially hazardous activities that support operations (explosives handling, chemical, etc.) must be certified or directly

supervised by certified personnel when performing those operations. WFF safety provides certification or will approve alternative certification programs. Range user personnel must provide documentation that supports requests for certification of their personnel.

- Range users must obtain approval from the Safety Office prior to any potentially hazardous operation.

- Range users must provide data as outlined in Section 8.0 of the Range Safety Manual to Safety Office for safety analysis.

- Range users must identify the minimum safety requirements for test operations. If range users determine that their safety requirements are more stringent than those imposed by WFF, they must coordinate these requirements with the Safety Office through the RSM.

- Range users must participate in formal and informal discussions to familiarize Range Safety personnel with all safety aspects of the mission.

- Range users must participate in real-time data evaluation for mission control; i.e., flight termination, as required by the Safety Office.

- Range users must notify the RSM of all meetings pertaining to the mission that involve safety related issues; i.e., Design Reviews, TIMs, and operational planning meetings.

- Range users are required to participate in failure/anomaly investigations and provide post flight data to the Safety Office, as necessary.

- Range users must provide a written waiver request to the RSM for any requirements specified in the Range Safety Manual that cannot be satisfied, and those that surface during WFF mission processing.

Range User Requirements. At WFF, range users are required to perform the following:

- Range users are required to design their systems to conform to the requirements established by the WFF Range Safety Manual.

- Range users are required to prepare and provide to WFF, through the RSM to the Safety Office, formal documentation pertaining to the launch mission for safety review. This documentation shall include information describing ground and flight safety systems, operating procedures, and any unique requirements of the mission.

- Prior to arrival at WFF, range users must submit written requests for waivers to the WFF RSM for any safety requirement that cannot be satisfied.

BIBLIOGRAPHY

1. GMI 1300.2, Goddard Management Instruction, Policies and Procedures for the Use of the GSFC/WFF Test Range
2. GMI 1771.1, Range Safety Policies and Criteria for GSFC/WFF
3. RSM-93, Range Safety Manual for GSFC/WFF and Supplement to Range Safety Manual

(RSM-93) for GSFC/WFF (additional requirements for Pegasus)

4. NASA/GSFC/WFF Airport Operations Manual
5. NASA/GSFC/WFF Aircraft Operations Manual
6. Instrumentation Engineering Branch Handbook Series, Volumes I - X:
   a. Volume I: Radar Facilities and Systems
   b. Volume II: Telemetry Facilities and Systems
   c. Volume III: Data Systems and Facilities
   d. Volume IV: Communications Facilities and Systems
   e. Volume V: Meteorological Facilities and Systems
   f. Volume VI: Optical and Photographic Systems
   g. Volume VII: Aircraft Instrumentation Systems
   h. Volume VIII: Quality Verification Facilities and Systems
   i. Volume IX: Computer Systems
   j. Volume X: Poker Flat Research Range Systems
   k. Abstract of Instrumentation Handbooks, Vols I through X
7. NASA GSFC/Wallops Flight Facility Tracking And Data Acquisition Systems Capabilities
8. NASA GSFC/WFF Timing System Synchronization Procedures Manual, Nov 93
9. GSFC/WFF Information Processing Laboratory’s Data Processing Handbook
10. NASA Sounding Rocket User’s Handbook
11. NASA/GSFC/WFF Host/Tenant Frequency Utilization Management Manual
12. GHB 1860.1B, NASA/GSFC Handbook, Radiation Protection - Ionizing Radiation
13. Geodetic Coordinates Manual For NASA Goddard Space Flight Center - Wallops Flight Facility
14. GHB 8800.2, NASA/GSFC Handbook, Goddard Space Flight Center Environmental Handbook
15. 14 CFR 1216.3 NASA Procedures for Implementing the National Environmental Policy Act (NEPA)
16. NHB 8800.11, Implementing The Provisions Of The National Environmental Policy Act
17. 40 CFR Parts 1500-1508, Council on Environmental Quality. Regulations For Implementing The Procedural Provisions Of The National Environmental Policy Act

18. GSFC/WFF Environmental Resources Document
19. An Experimenter's Guide to the NASA Atmospheric Sciences Research Facility, March 1994
20. GSFC/Wallops Flight Facility Space Utilization Handbook, Facilities Engineering Branch
21. Range Commanders Council - Documentation Group (RCC-DG) Document 501-90, volume I, II, and III

APPENDIX A
WIND WEIGHTING PROCEDURES

Wind Effects for Sounding Rockets - Wind can significantly affect the flight of rockets. Unguided rockets must be wind-corrected to fly the planned trajectory. Prelaunch winds (initially taken at approximately 3 hours prior to launch) are used to determine the launch azimuth and the launch elevation angle which will result in the vehicle flying the desired trajectory. High or gusty winds (on the order of 30-35 mph or gusts above 45 mph) may make it unsafe to launch a rocket. Even for guided rockets, the winds may get so strong that they saturate the vehicle guidance system. A rocket is normally wind-corrected so that the desired trajectory is achieved and the predicted vehicle impact of the last stage is in the planned area. This may not result in the booster stage impact being in its original planned impact area. Separate booster wind correction and drift calculations must also be made to determine it's impact location and to assure that the predicted booster impact location is in a safe area.

Wallops Range Safety personnel use a 5-degree of freedom computer program named SENSE 5D, which is tailored after the Lewis or Unit Wind method, to aid in determining the proper launcher settings to be used for any given sounding rocket mission. This wind weighting procedure is used pre-launch as a predictor.

Parameters such as:

- Tower Tilt - number of nautical miles per degree of elevation,
- Ballistic Wind - sum of the weighted winds for each altitude layer
- Unit Wind - number of nautical miles per feet per second of the ballistic wind
- f curve - the sensitivity of the launch vehicle to wind versus altitude

are computed by the SENSE 5D computer program and are used in determining the adjustments to the launch flight azimuth and elevation angles for sounding rocket launches.

During actual launch operations, the SENSE 5D program uses actual wind data taken from balloon tracking information and used to fine tune the launcher settings to obtain the desired trajectory and stage impact locations. Radar reflective balloons are released at predetermined times prior to the scheduled launch time. Also, there is an occasional use of radio-sonde equipped balloons for this purpose. These balloons are tracked by radar's located on the Wallops range. This tracking information is received/processed and used in the SENSE 5D computer program, which outputs the appropriate launcher settings necessary to compensate for the "actual" winds and achieve the desired trajectory and stage impact locations. These balloons are released and tracked to the burnout altitude of the final stage or a maximum of approximately 100,000 feet in altitude. Low altitude (< 300 feet) wind data is obtained from anemometers mounted on towers located at various places on the Wallops range. As launch time approaches, balloons are only tracked to 5000 feet with the last one released at approximately 15-20 minutes prior to launch. With an ascent rate of approximately one thousand feet per minute, this allows ample time for processing of radar tracking data and subsequent determination of appropriate launch parameters as near to launch conditions as practical.

An example of a wind weighting calculation for a typical sounding rocket second stage is shown below:

To compute the adjustments to vehicle flight azimuth and elevation angle required to compensate for wind, it is first necessary to select the altitude levels that are representative of the mission. The Black Brant X vehicle is used for this example.

The change in vehicle sensitivity (Delta F), see Figure A - 1, to the wind in the appropriate altitude level is multiplied by the N/S and E/W wind profiles (shown in the table below) to obtain the ballistic wind for each altitude level selected. It is important to note that approximately 80% of the wind effects occur during the first stage flight of a sounding rocket.

Table A - 1 below shows the altitude levels, vehicle sensitivity (Delta F)/altitude interval, N/S and E/W wind profile and the resultant ballistic winds used for this example.

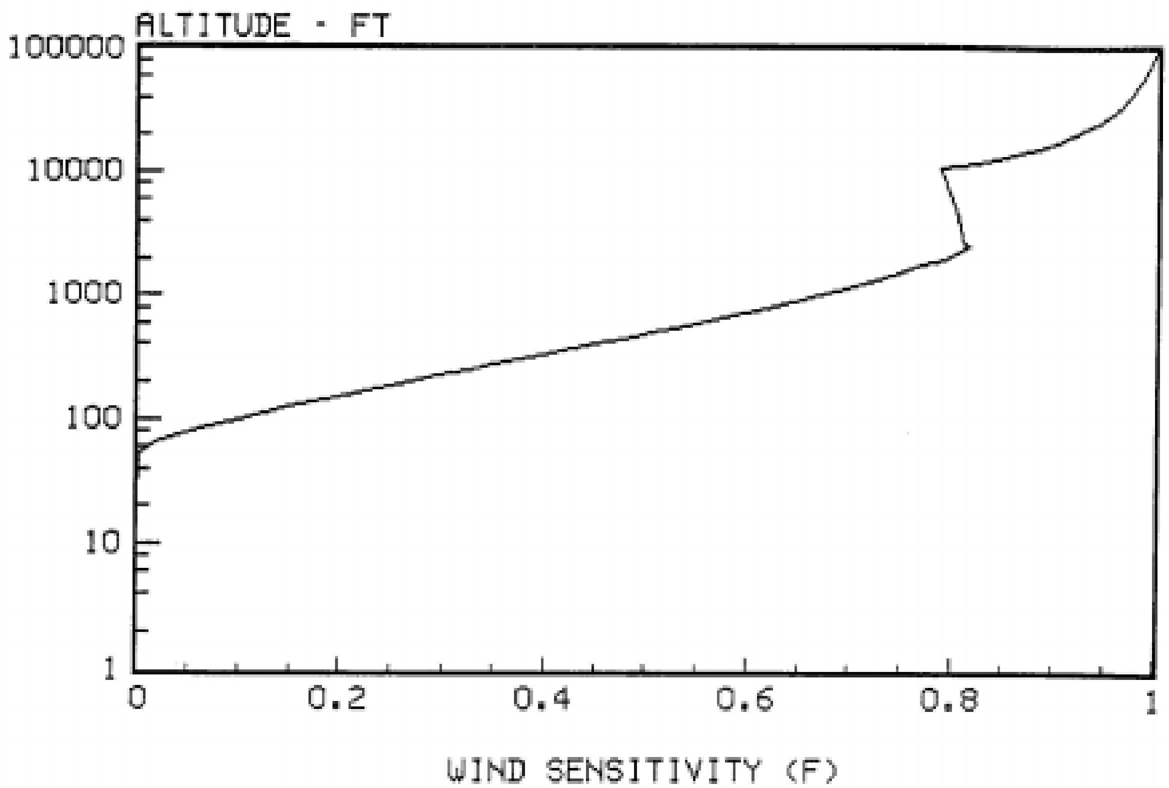

Figure A - 1: Vehicle Altitude Vs Wind Sensitivity

ALTITUDE (FT)	ΔF VS ALT LAYER	ACTUAL WINDS		BALLISTIC WIND	
		N/S $\dot{X}$ FT/SEC	E/W $\dot{Y}$ FT/SEC	N/S $W\dot{X}$ FT/SEC	E/W $W\dot{X}$ FT/SEC
33 - 100	.100	20	-20	+2.0	-2.0
100-225	.194	21	-25	+4.1	-4.9
225-400	.153	22	-20	+3.4	-3.1
400-800	.171	28	-15	+4.8	-2.6
800-1600	.136	35	-10	+4.8	-1.4
1600-2500	.064	50	-15	+3.2	-1.0
2500-10,914	-.029	-20	-20	+0.6	+0.6
10,914-16,000	.097	-45	45	-4.4	+4.4
16,000-27,500	.063	-50	20	-3.2	+1.3
27,500-45,000	.029	-28	25	-0.8	+0.7
45,000-98,836	.022	-22	15	-0.5	+0.3
Totals	1.000			+14.0	-8.0

Table A - 1: Wind Weighting Data

The individual ballistic winds are then summed to obtain the total effect of the N/S and E/W wind profiles, i.e. +14 for N/S (from the north) and -8 for E/W (from the west) in this example. The total ballistic wind for the N/S (+14) and E/W (-8) components is then multiplied by the appropriate unit wind factor for crosswind (2.0 N/S) and tailwind (1.96 E/W) obtained from reference 31. This is shown in the following expression:

N/S component = +14 ft/sec X 2.0 nm/ft/sec = +28 nm

E/W component = -8 ft/sec X 1.96 nm/ft/sec = -16 nm

This will have the effect of driving the impact point from the desired location as shown in Figure A - 2 below:

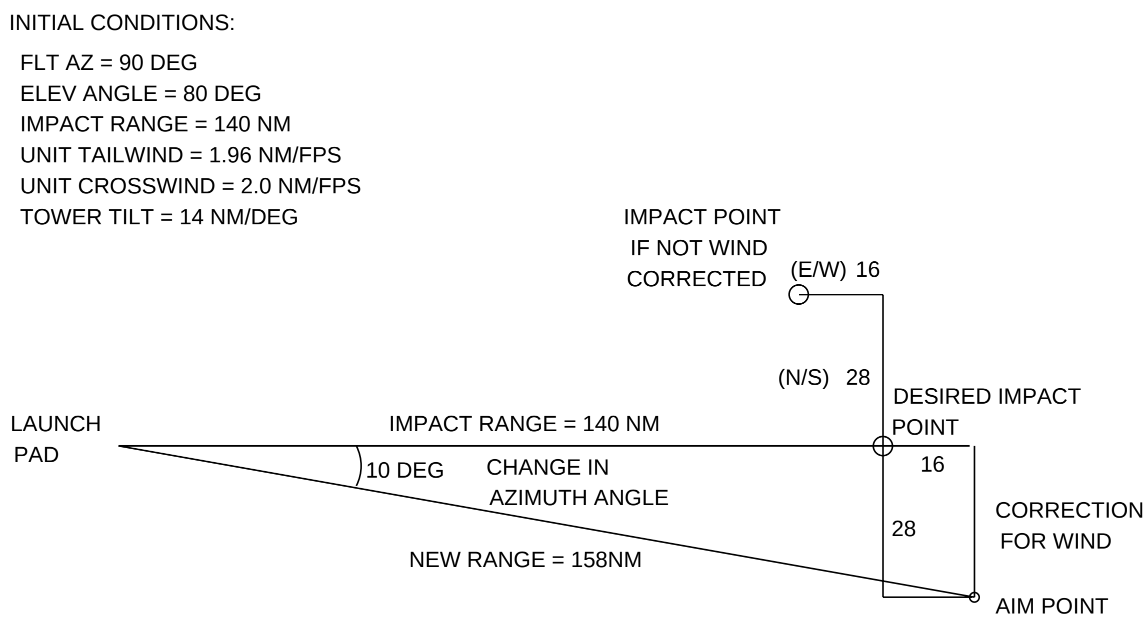

Figure A - 2: Second Stage Impact Point Wind Correction

In order to compensate for the wind effects, the flight azimuth and elevation angles must be adjusted. First a computation must be made to determine the new range component which has resulted from the wind effects. This is found by:

$R^2 = (156\ \text{nm})^2 + (28\ \text{nm})^2$

$R = (24{,}336 + 784)^{1/2} = 25{,}100^{1/2}$

$R = 158\ \text{nm}$

Next it is necessary to compute the change in the flight azimuth. This is done by solving for the angle made between the launch point and the adjusted aim point shown in the above figure.

Since the sine of the angle = 28 nm/158 nm = .1772, then the change in the flight azimuth is approximately 10^0. Therefore, $90^0 + 10^0 = 100^0$ which is the adjusted flight azimuth for this example.

To find the new launch elevation angle the following expression is used:

El angle = New Range/Tower Tilt = 158 nm/14 nm/deg_{35} = ~11.3^0

The adjusted elevation angle is then, $90^0 + (-11.3^0) = 78.7^0$

Hence, the vehicle must be launched on a flight azimuth of 100^0 (to compensate for wind effects) with an elevation angle of 78.7^0 (to compensate for the increased range) to obtain the desired trajectory and impact point at 140 nm.

The adjustments to the flight azimuth and the elevation angle has a direct effect on the first stage nominal impact point. The new impact point must be determined and appropriate action taken by range safety personnel to assure that the impact location is clear of boats, ships and aircraft during sounding rocket launch operations.

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